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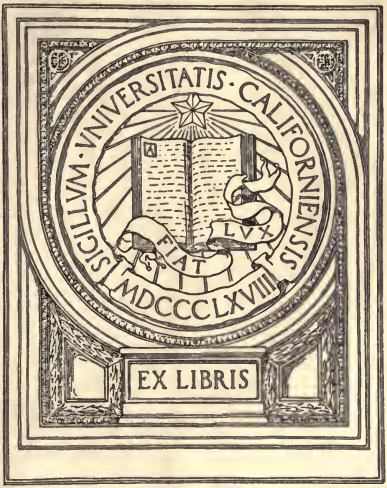

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OF

ELECTRIC CAR EQUIPMENT

BY

EUGENE C. PARHAM, M. E.

AND

JOHN C. SHEDD, Ph.D.

McGRAW-HILL BOOK COMPANY

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PREFACE

The present volume is the second of two, the first being entitled "Shop Tests on Electric Car Equipment." In the first volume many of the more common and some less common, but useful, equipment tests were so described as to be readily available to men of limited testing facilities and experience. The second volume continues this effort to present the testing subject in a simple and direct manner and embodies tests and explanations that could not well be included in the first book. It is believed that the two books cover a large part of the equipment-testing field in a way not previously attempted, both in the manner of presentation and in that, information hitherto scattered, has been brought within the scope of two comparatively small books. In giving numerous rules, examples, solutions, directions, notes and rehearsing questions, the authors have tried to treat the subject in a practical manner; the purpose being not only to reach nonmathematical readers, but to give mathematical readers of limited experience a line on how such tests are actually made with the facilities usually available, rather than how they might or should be made under ideal conditions. If these objects have been accomplished we feel that the mission of the book has been attained.

THE AUTHORS.

NEW YORK,
April 1st, 1910.

206524

TABLE OF CONTENTS

PART I—STATIONARY TESTS

CURRENT COLLECTORS—
Overhead Trolley 1
Conduit System 4
Third Rail System 6
CAR FUSES—
Blowing Tests 7
Calculation of Fuse Capacity 8
Fuse Test Requirements 9
CAR CIRCUIT BREAKERS—
Periodic Tests 10
Adjustments 11
Auxiliary Apparatus 13
CAR CONTROLLERS—
Mechanical Tests 15
Electrical Tests 18
Inspections 22
CAR STARTING COILS—
Ohmic Resistance 25
Changed Conditions 29
CAR LIGHTNING ARRESTERS—
Connection Tests 33
CAR WIRING CABLES—
Preliminary Considerations 37
Tagging and Insulation Tests 39
CAR MOTORS—
Brush Holders Requirements 42
" " Irregularities 44
" " Miscellaneous Topics 51
Motor Insulation Tests 55
" Circuit Test 56
Field Coil Polarity Test 61
Carbonized Field Coils 63
Armature Clearance 66

PART II—MOTION TESTS

MOTOR BALANCE TESTS—
Voltmeter Method 70
Lamp Circuit Method 74
Ammeter Method 76
Milli-Voltmeter Method 78
Value as a Field Test 82
MOTOR HEATING TESTS—
Object of Heat Test 83
Test Connections 84
" Instructions 86
" Readings 87
EFFICIENCY TESTS—
Definitions 90
Electrical Efficiency Test 91
Commercial " " 92
ENERGY ABSORPTION TESTS—
Introductory 95
Indicating Wattmeter Methods 96
Voltmeter-Ammeter " 97
Record Sheets 99
Analysis of Test Sheet 100
MISCELLANEOUS TESTS—
Speed Tests 112
Acceleration Tests 114
Retardation Tests 119
Train Resistance 122
Horse Power of Traction 125
Total Horse Power of Operation 128
HELP TO THE INJURED—
Reviving Shocked Persons 131
Relieving Burns 133
Rehearsal Questions 135
Index 154

INDEX OF RULES

		PAGE
To find	size of copper fuse wire	8
"	"shocking" voltage	31
"	area of brush contact	50
"	brush pressure	51
"	center to center brush count	53
"	inside brush count	54
"	per cent. difference of meter readings	72
"	number of lamps for given voltage on balance test	74
"	voltage for motor in balance test	75
"	speed from voltage readings	87
"	temperature rise from rise in resistance	88
"	degrees Fahrenheit from degrees Centigrade	89
"	" Centigrade from degrees Fahrenheit	89
"	per cent. efficiency from output and input	91
"	electrical efficiency from known voltage current and resistance	91
"	Watts absorbed in brake test	93
"	" input of motor from current and Voltage readings	94
"	watt hours from indicating wattmeter	97
"	car weight in tons from weight in pounds	101
"	rated horsepower of equipment	101
"	time in hours from time in minutes	102
"	average voltage	103
"	" current of all readings	104
"	" " of current readings	104
"	" power, in watts, of all readings	106
"	" " " " of power readings	106
"	" car speed	106
"	watt hours absorbed	107

PAGE

To find kilowatt hours from watt hours 107
" " horsepower hours from kilowatt hours 107
" " average kilowatts (or kilowatt hours per hour) 108
" " " kilowatt hours per mile 108
" " " " " " ton 109
" " " kilowatts per ton (or kilowatt hours per hour per ton) 109
" " average kilowatt hours per ton-mile 110
" " speed in miles from rail count—30-ft. rails... 112
" " " " " " rail count—60-ft rails.... 112
" " " " " " pole count 113
" " " " " on measured track 113
" " acceleration in miles per hour per second 114
" " retardation " " " " " " 120
" " feet per second per second from miles per hour per second 115, 120
" " average speed during acceleration 116
" " maximum " due to " 116
" " force in pounds to produce given acceleration in miles per hour per second 117
" " force in pounds to produce given acceleration in feet per second per second 118
" " horsepower of acceleration 118
" " total train resistance 123
" " grade resistance 124
" " average horsepower of traction 125, 126
" " horsepower required on grade 127
" " rise in feet of given grade 127
" " per cent. grade from known rise 128
" " total horsepower of operation 128

Miscellaneous Tests of Electric Car Equipment

PART I STATIONARY TESTS

CURRENT COLLECTORS

OVERHEAD TROLLEY

1. Rough Pressure Test. The trolley wheel should safely engage the trolley wire at all heights. In tunnels and culverts, the wire may be low and the pressure of the wheel, excessive; at steam road crossings, the wire may be high and the pressure so weak that the wheel jumps—a dangerous condition. The rough pressure test is to try the pressure when the pole is almost vertical: the test is made as follows:—

2. *Directions.* To apply the rough test for trolley pole contact pressure, Pay out the rope and let the pole go to a vertical position; if it does so promptly, the pressure is sufficient for all conditions. If not, Increase the pressure with the adjusting nut and repeat the test.

3. Scale Pressure Test. This test is made with a spring scale on which can be read the pounds pull required to just lower the wheel from a stretch of wire of standard height.

4. *Directions.* To measure the pressure of the trolley wheel against the wire with a spring scale,

Apply the scale to the wheel at right angles to the wire and read the scale when the wheel is just held from the wire.

Fig. 1 shows how to apply the scale. The upward force with which the wheel presses the wire depends on the strength of the spring, the length of the pole and the angle it makes with the top of the car. To read the pressure directly, the scale must stand at right angles to the wire or along line *b* in Fig. 1. The vertical pull required to lower the wheel from

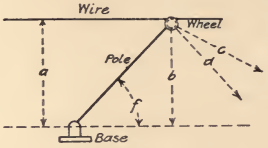


FIG. 1

the wire exceeds the pull along line *d*, at right angles to the pole, but it gives the actual pressure of the wheel against the wire. The reading when the scale is applied along line *d* is smaller than along any other line, as *b* or *c*. This is shown by Table I. The stretch of test wire must be at standard height and the wheel must rest under a section free from sag, otherwise, when the pull is applied, the wire will follow the wheel down and break contact where the pressure is greater than at standard height. To get uniform results, all tests must be made under the same stretch of wire. Formerly, the height of wire and length of poles were such as

to give a pole-roof angle, f (Fig. 1) of about 45°; but increased height of cars and length of poles without corresponding increase in height of wire have reduced this angle.

5. Pressure Measurements. Table I gives readings on a 12-foot pole with roof angles of approximately 45° and 30°. Where the pole-roof

TABLE I

ROOF ANGLE 45°		ROOF ANGLE 30°	
Pull in Lbs. Rt. Angle to Pole	Pull in Lbs. Rt. Angle to Wire	Pull in Lbs. Rt. Angle to Pole	Pull in Lbs. Rt. Angle to Wire
29.3	40	34.0	40
25.0	35	30.0	35
21.0	30	26.0	30
18.0	25	21.5	25
14.0	20	17.0	20
11.0	15	13.0	15

angle does not approach either of these values, the vertical pull for adjusting the trolley pole pressures of cars can be obtained by following the directions given below:—

6. *Directions.* To adjust trolley pressures to equal standard values, Run a standard car under a standard stretch of wire and adjust the vertical pull to the desired value—30 lb. for example. Thereafter, all standard cars adjusted under the test wire to give a vertical pull of 30 lb. will have the desired pressure.

7. *Remarks.* Trolley pole pressures on different roads are as different as are the opinions as to what their values should be; on the same road,

pressures are different owing to varying car heights, pole lengths and neglect of adjustment. Excessive pressure unduly wears both wheel and wire, makes the pole hard to replace under the wire and invites damage to pole and line when the wheel jumps the wire. Deficient pressure impairs the centering action of the device and makes it easier for a kink in the wire, a rough trolley wheel groove or rough track, to throw the wheel from the wire. The best pressure is determined by experiment; it increases with the car speed because the higher the speed the greater the blows due to irregularities: the pressure must be sufficient to restore the wheel before the impact of a blow can force it down a distance exceeding the depth of the wheel groove. In city service the pressure used varies from 20 to 30 lb.; in interurban high speed service, from 30 to 50 lb.

CONDUIT SYSTEM

8. The current collector used on a conduit system is called a **plow.** The tests to which plows as a whole are subjected are the contact-shoe pressure-test and the insulation-test.

9. Pressure Test. The test used in a car house consists in the slapping of the springs together by hand to see that they are neither weak nor broken and that the action is free. The distance apart of the slot conductors is 6 inches; the distance between contact shoe surfaces on a standard plow, dimension *a*, Fig. 2, is 8½in. In service, then, each spring is compressed 1¼ in. To do this, a pressure of

approximately 25 lb. is required. As the shoes have a wearing surface of about 10 sq. in., the pressure per sq. in. is 2.5 lb. Knowing the amount

FIG. 2

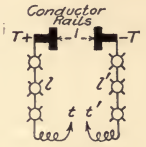


FIG. 3

of compression, the desired pressure per sq. in. and the area of the contact shoe surface, a shop pressure test can be made as follows:—

10. *Directions.* Given the shoe contact surface area in sq. in. and the desired pressure per sq. in., Multiply them together to get the total pressure in pounds; this pressure in the form of a weight is then applied to the spring and should produce a compression of $1\frac{1}{4}$ in. If the compression is greater, the spring is weak; if less, the spring is too strong.

11. Insulation Test. Insulation is best tested with a voltmeter, but a lamp test circuit is generally applied as follows:—

12. *Directions.* To test plow insulation with test lamps, connect the lamps as indicated in Fig. 3. The test points are first touched together to see that the test circuit is all right. Next, test the insulation between the shoes and between each shoe and the iron sheathing of the plow body. Finally, touch each shoe and its corresponding

body terminal, to see that the circuit between them is intact, as indicated by the lighting of the test lamps.

13. *Remarks.* When using a metallic return system as a source of voltage with which to test the insulation of any device, it is well to hang the device up or to lay it upon wood, to minimize the danger of a shock or burn should one side of the system be grounded, as is generally the case. (See Fig. 37, "*Shop Tests on Electric Car Equipment*"). It is on this account that half of the test lamps are connected in each of the test lines—Fig. 3.

THIRD RAIL SYSTEM

14. The pressure of the contact shoe used on a third rail system is due either to the weight of the shoe, 25 or 30 lb., or to an equivalent spring, the latter being used where the rail is housed. The main feature of inspection here is the shunt, provided to keep the shoe pins and links from carrying sufficient current to blister and thereby roughen them.

CAR FUSES

BLOWING TESTS

15. Instantaneous Test. This test is made to determine the approximate value of the current required to blow a given fuse instantaneously.

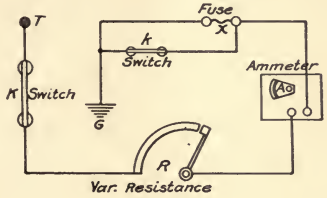


FIG. 4

The connections are shown in Fig. 4, where x is the fuse and K, a quick-break switch, or breaker. The test is made as follows:—

16. *Directions.* To determine the value of the current required to blow a given fuse instantaneously, Repeatedly insert fuses, close K, adjust R and open k, switch k being closed as soon as the fuse blows, so that the current that blew the fuse can be read on the ammeter, A.

17. Time Element Test. The *time element* of a fuse is the time elapsing between the closing of the circuit (in this case) and the blowing of the fuse. The test is made as follows:—

18. *Directions.* To make a time element test with the connections of Fig. 4, Adjust R to give a

current certain to blow the fuse promptly; then open k and close K; now repeatedly insert fuses, adjust R, open k and close K, noting the time with a stop-watch, elapsing between the closing of K and the blowing of the fuse, until the time elapsed is the time element desired.

19. *Note.* This test is useful where it is desired to so fuse a car that the fuse will blow a certain number of seconds after the current for which the breaker is set may have maintained, owing to the breaker being out of order.

20. Operating Test. This test, of more value than either of the preceding, consists in fusing cars under actual operating conditions and noting their behavior under proper handling. Too large a fuse affords little protection to equipment; too small a fuse causes prohibitive delay in replacements. Cars of different capacity and weight should be protected by different capacities of fuse.

CALCULATION OF FUSE CAPACITY

21. The approximate size of copper wire to be used as a fuse to protect an equipment of given h.p., operating under average conditions, can be found by applying the following rule:—

22. *Rule.* To find the size of copper fuse wire for an equipment of given h.p., Multiply the motive power of the equipment by 70 and find the number nearest to this product in the circular mils column of a B & S wire table; opposite, will be the size of wire required.

23. *Example.* What size of copper wire should be used for a fuse on a car equipped with 4 fifty h.p. motors?

24. *Solution.* $4 \times 50 = 200$ h. p. and $200 \times 70 = 14{,}000$. The number nearest to this in a B & S wire table is 12,996, which corresponds to a No. 9 wire.

25. *Note.* This rule does not apply to cases where two or more wires are twisted together, as the capacity of such a fuse depends upon how tightly the wires are twisted.

FUSE TEST REQUIREMENTS

26. Copper wire is commonly used for fuses, because it is cheap, uniform in diameter, easy to install, and is in no way special. Except under well defined conditions, data on fuse blowing may be misleading, because the blowing value depends upon the length of fuse, purity of the copper, size of fuse terminal blocks, method of fastening, position and location of the fuse box and upon whether there are forces provided to pull the fuse apart when it softens. To find the size of the wire to be used in a given fuse box, all tests should be made on that type of box and under the same conditions.

CAR CIRCUIT-BREAKERS

ADVANTAGES OF PERIODIC TESTS

27. Certainty of the good condition of car breakers has the following advantages:—In damage suits based on real or imaginary injuries caused primarily by fright due to blowing of a fuse, controller short-circuit or other demonstration, ability to prove regular breaker inspection has weight with judge and jury. Adjusted breakers compel the motorman to handle the controller carefully; this saves energy, because a too rapid advancement of the controller increases the current at so fast a rate that, except where stops are few, the speed never reaches a value corresponding to existing load conditions. With good breaker adjustment, the maximum current per car is fixed, thereby decreasing the peak of the current demand of that car on the station. With good breaker adjustment a car will be "run in" promptly for a slight irregularity that would become serious were it permitted to persist. Fixing the maximum current per car minimizes the chances of excessive current causing a burn-out likely to frighten platform passengers to the point of jumping from a moving car. Good adjustment decreases the liability of fire. It gradually educates motormen to careful handling of controllers, so that the current value of the adjustment can be decreased toward

a point where the maximum possible current does not greatly exceed the overload current for which the motors are rated.

CIRCUIT-BREAKER ADJUSTMENTS

28. Ammeter Method. This test is made with the connections of Fig. 5, where K is a switch or breaker; A, an ammeter of range exceeding the test current; F, a fuse or breaker; R, a water resistance; r, an auxiliary resistance which, in

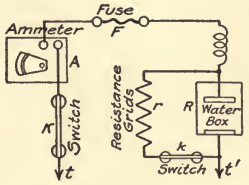


FIG. 5

conjunction with switch k, affords a quick means of approximating full test current. By means of test lines t and t', the test circuit is connected in series with the car breaker to be tested. Assuming an adjustment of 250 amperes, with a line voltage of 500 volts, if r is 2.5 ohms, there will be a current of 200 amperes on closing k and K, leaving but 50 amperes to be carried by the water rheostat.

29. *Directions.* To adjust car breakers with the connections of Fig. 5, Adjust r to give 90 per cent. of the current. With all switches open, the water box plates pulled apart, the test lines on the

closed breaker to be tested and the ammeter connected to deflect in the proper direction, close k, then K and adjust R until the ammeter indicates 250 amperes or the car breaker opens. Repeat these operations until the car breaker is adjusted to act within 5 per cent. of 250 amperes.

30. Limit Breaker Method. The preceding test is reliable, but is slow and requires an ammeter which is not always available. Fig. 6 shows the connections of the limit breaker method, which requires a meter only initially for adjusting breakers A and B. All other letters mean the same as in Fig. 5. Assum-

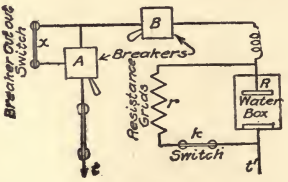


FIG. 6

ing that the car breakers are to be adjusted for 300 amperes, limit breaker A would be set for 275 and B for 325 amperes, the test being made as follows:—

31. *Directions.* To adjust car breakers with the test connections of Fig. 6, Connect the car breaker in series with the test circuit; close all breakers, then switches k and K; handle r and R as in the preceding test; repeat the blowing of the car breaker and its readjustment, until it operates

between breakers A and B. This done, the car breaker is adjusted.

32. *Note.* Switch x, Fig. 6, is a short-circuiting path, from the negative side of the blow-out coil to the negative terminal of the breaker, to bridge the breaker contacts, so that when it acts it will not open the circuit, but will serve simply as a signal.

AUXILIARY APPARATUS

33. The Water Rheostat. Any form of water rheostat having a cross-section of 6 sq. ft. and an inside length of 5 ft. will answer for breaker and miscellaneous tests requiring a large current without foaming. For making the water conducting, table salt is added, a handful at a time as needed. When the resistance of the box becomes too low, water is drawn off and cold water admitted. In out-of-door testing where steam and foam are not objectionable, a barrel can be used.

34. Attaching Test Lines (First Method). In breaker testing the test lines must be connected

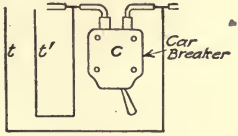


FIG. 7

to the car breaker. This is best done by baring the breaker wires for a short distance and placing

lengths of garden hose over the bare places so that they will be easy to shove along when applying the test lines. In Fig. 7, all letters mean the same as in Figs. 5 and 6, test line t being connected to the + side of the breaker to be tested and t', to the — side of the supply circuit. This method is the most general, being applicable to all systems and with minimum chances of contact troubles.

35. Attaching Test Lines (Second Method). To test breakers on a ground return car, test line t may end in a hook to engage the trolley wheel; the pole is lowered, the motors cut out in a controller, to prevent starting; one controller placed on the last parallel notch, to save the car starting coil and wires, and the brake set as a factor of safety. All current must pass through the test circuit including the water rheostat, the adjustment being the same as already described.

36. *Note.* Other methods of attaching the test lines may be suggested by local conditions. On a slot system, the two breakers can be tested one at a time by placing one test line on a plow shoe and the other on the corresponding controller trolley connecting-post.

CAR CONTROLLERS

MECHANICAL TESTS

37. Cylinder Interlocks. Modern controllers require that the main cylinder at the "off" position be immovable when the reverse cylinder is at the "off" position; and that the reverse cylinder be immovable when the main cylinder is on a current notch. The first condition compels the motorman to lock his controller when leaving it and prevents reverses on opposite ends from being set to oppose each other, unless this has been maliciously or accidentally done with a wrench. The second condition prevents reversing without first throwing off the power, reverse switches not being constructed to break an arc and it being unwise to reverse with power on, owing to increased liability of blowing the fuse or circuit-breaker.

38. *Directions.* To test the proper condition of the controller interlocks; see that the reverse handle is immovable when the controller handle is on a current notch and that the controller handle is immovable when the reverse handle is in the "off' position.

39. Cutout-Switch Interference. When either cutout-switch is operated, it moves an interference that prevents advancement of the main cylinder beyond the last series notch. Defective interference may result in irregular circuits, in burning of tips and fingers and in jerking the car.

40. *Directions.* To insure good condition of the interference, operate the cutout-switches one at a time, in each case seeing that the cylinder cannot be moved past "series."

41. Alinement Requirements. Alinement tests are made in order to see that the main fingers line up vertically with each other; that the reverse fingers line up vertically with each other; that all fingers line horizontally with the corresponding tips and that all contacts intended to be made simultaneously are so made.

42. Vertical Alinement. With a well alined cylinder as a gage, vertical alinement of the fingers can be judged by the eye, by repeatedly moving the cylinder "on" and "off" and noting how the fingers touch. Alinement can also be judged with a straight edge, as in Fig. 8, care being

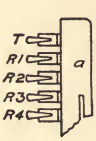


FIG. 8

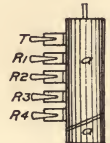
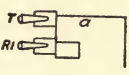


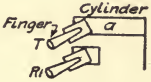
FIG. 9

taken to hold the straight edge vertically. By mounting the straight edge on a shaft to be installed like a cylinder, as in Fig. 9, a true test can be made. On request, the factory will provide jigs for alinement testing. In the case of the reverse fingers, alinement by eye will usually do.

43. Horizontal Alinement. The test for horizontal alinement is made by the eye and consists in seeing that no one of the fingers is above or below its corresponding tip, Fig. 10, or across the tip, as in Fig. 11. The first condition may be due to wear in the lower cylinder bearing, to error in the cylinder or finger board or to the board being set too high or too low. The second condition is, on the main cylinder, generally local to a finger or two



FIG, 10



FIG, 11

and can be corrected by straightening the finger. On the reverse, horizontal alinement defects are common, owing, probably, to the fact that as this cylinder does not have to break an active circuit, less care is taken to keep its dimensions standard. The reverse fingers and contacts should register truly, because they carry as much current as many of the main fingers, are closer together and very liable to contact troubles.

44. Notch Spacing. This term refers to the arc through which the tips move when the cylinder is advanced a notch. It can be judged by the eye if the vertical alinement of the fingers is correct. The vertical alinement may be good, but, owing to the fingers being too long or too short or to the board

being too close to the cylinder or too far from it, or to the index wheel being in error, the fingers may fail to make flush contact on one, several or all notches. In Fig. 12 the fingers on the first position do not extend far enough, while in Fig. 13, they

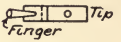


FIG. 12

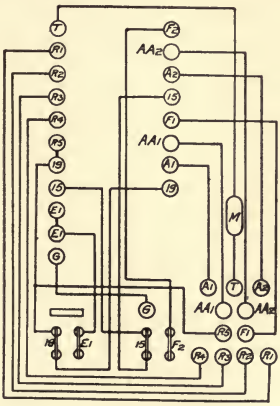
FIG. 13

extend too far, with the result, in the latter case, that when the cylinder is moved from "off" position, it will jump a little over the first notch, make the combinations of the second notch, disconcert passengers by jerking the car, and burn the contacts. If the fingers register on some notches but not on others, it points to error in the cylinder. Any failure to register in every position must be investigated and the trouble removed.

ELECTRICAL TESTS

45. Open-circuit. The open-circuit test is made to see that all fingers and posts that should be connected *are* connected; it is made with a lamp or bell circuit and requires either familiarity with the controller internal connections or ability to use a sketch like that of Fig. 14, a sketch of the internal connections of the K 10-K 11 controllers. This sketch shows the T post connected to the bottom of the blow-out coil, M, the top of which connects to finger T; also finger R_1 connects to post R_1; fingers R_5 and 19, to the top left-hand post of No. 1 cutout-switch, also to connecting-board post

R_5; finger 15, to the top left-hand post of No. 2 cutout-switch, also, through the switch, to reverse finger 15 and so on, each post or finger being con-



FIG, 14

nected to another post or finger. The open-circuit test can be made as directed below:—

46. *Directions.* To test controller internal connections for open-circuit, Apply one test point to any post or finger and the other to the post or finger to which the first is supposed to be connected, both cylinders being at "off" position: if the lamps fail to glow, the cause must be located and removed.

47. Complete Circuit. The complete circuit

test includes both cylinders and, on the controller bench, is made as follows:—

48. *Directions.* To test a controller for complete-circuit through both cylinders, Short circuit the posts ordinarily connected by the car devices; put the reverse on an operating position and the main cylinder on notch 1; place one test point on connecting post T and touch the other to the successive points of the current path indicated below; the lamps will glow until the free test point passes an open-circuit.

49. *Note.* On the K 10-K 11 controllers, with jumpers between A_1-AA_1, F_1-E_1, A_2-AA_2, F_2-G and R_1-R_5, the test current path is T-M-T-cylinder-R_1-R_5-19-19-19-reverse cylinder-A_1-A_1-AA_1-AA_1-AA_1-reverse cylinder-F_1-F_1-E_1-E_1-E_1-E_1-cylinder-15-15-15-15-reverse cylinder-A_2-A_2-AA_2-AA_2-reverse cylinder-F_2-F_2-F_2-G. Suppose the test lamps to glow in each case until contact with the reverse tip under fingers F_1 and AA_1: the open-circuit would lie between finger AA_1 and the reverse tip and pressing the finger down, thereby closing the circuit, would light the lamps. The test can be applied on all notches, in both reverse positions and with the cutout-switches cut out one at a time.

50. Short-circuit. With a knowledge of the internal connections or the aid of a diagram, the short-circuit test is as follows:—

51. *Directions.* To test controller internal connections for short-circuit, Hold one test point on any finger or post; then touch the other to all

other fingers and posts; in no case should the lamps glow between parts not normally connected.

52. Ground. A ground is a special case of short-circuit; on a bench the test for ground is made as follows:—

53. *Directions.* To test controller internal connections for ground, Hold one test point on the frame and touch the other successively to all posts and fingers; the lamps should fail to glow except when contact is made with a part marked G.

54. *Note.* Where controller benches are metal covered and in contact with grounded pipes, judgment must be used when the source of voltage is a ground return or a grounded metallic return circuit, for should the test point in contact with the controller frame happen to be "trolley" the lamps will glow although the controller may have no fault. Thus in Fig. 15, T is the positive side of a metallic

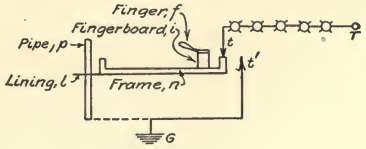


FIG. 15

return circuit of which the negative side is grounded at G. The metal bench cover is l; p, a gas pipe; n the controller frame; f, a finger and i, the finger board. If in testing f for ground, t be touched to the finger and t' to the frame, the test lamp indi-

cation would be correct; but should t' be touched to f and t to n, the lamps will glow the instant t touches n whether t' has yet touched anything or not

INSPECTIONS

55. Main Features. The main features of controller inspection are:—

1. Back and door linings to be intact.
2. All iron painted and clean.
3. Charred parts scraped and shellacked or renewed.
4. Partitions scraped and filled or renewed.
5. Fiber separator between cylinders o. k.
6. Fingers trimmed, alined, renewed and pressure adjusted.
7. Interlocks and interference perfect.
8. Action of notching mechanism prompt and decisive.
9. Soldered joints perfect.
10. Wire insulation intact.
11. Cylinder castings tight on shaft.
12. Blow-out coil in good shape.
13. Cutout-switches o. k. and workable by hand.
14. Door a good fit and the wing nuts turnable.
15. Blow-out magnet wrench screwed home.
16. Arc deflectors free from interference with fingers.
17. Controller top tight.
18. Cylinder bearings o. k.
19. Water guards in place.
20. Cylinder tips alined and tight.
21. Handles to fit.

56. Precautions. On a car, the controller and brake staff brackets should be securely bolted to the dash rail, so as to ground the controller frame independently of the controller internal ground, thereby minimizing the chances of shocking a passenger should the ground wire become loose. Before connecting the ground wire, the lamp test should show the controller frame to be perfectly grounded through the dash rail.

57. *Note.* On a metallic return system there is no ground wire, so it is not customary to consider this feature.

58. *Remarks.* Locating defects in operating controllers will be considered elsewhere, but it may be said here:— An open-circuit that affects operation on both ends of a car, is not in a controller, because the two controllers are in parallel, and parallel circuits constitute independent paths for current.

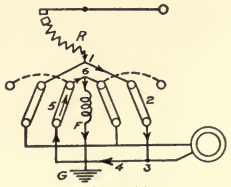


FIG. 16

If the reverse switch on one end of a car is in a certain position and a motorman, unaware of the

condition, tries to start with the other reverse switch in the same position, a fuse or breaker will act as soon as advancement of the controller cuts out sufficient resistance, the path of the short-circuiting current being indicated in Fig. 16 by means of two old reverse switches. The short-circuit path is shown by the arrow heads.

CAR STARTING COILS

OHMIC RESISTANCE

59. Requirements. The resistance of a starting coil can be measured on or off the car, as explained in "*Shop Tests on Electric Car Equipment*," Arts. 27-30. The best resistance value is governed by smooth starting under average conditions of load and voltage. A coil that will start one car satisfactorily, will start a heavier car sluggishly and a lighter one with a jerk. The best test is to install a coil and try it under operating conditions, and note whether it gives smooth starts or not and whether it heats too much. If parts of the coil show discoloration after several days of operation with careful handling, the cross-section of the resistance metal must be increased to increase the current carrying capacity and a greater length of it must then be used to keep the resistance the same. Starting coil resistances should be periodically tested and defective sections renewed. Properly maintained coils minimize abuses in controller handling and permit the car breakers to be set at a lower operating value, thereby decreasing the maximum possible current per car.

60. Section Test. As voltage applied to a series circuit distributes itself according to the distribution of resistance, the sectional distribution of starting coil resistance can be determined with a

voltmeter. The sum of the drops on the separate sections should equal the drop across the whole coil.

61. *Directions.* In applying a voltmeter to determine the distribution of resistance in a starting coil, Pass a small current through the coil, take the drop on the whole coil, then on each section, then on the whole coil again to insure all readings being taken at the same line voltage. In each case write down the reading and designate the terminals from which it was taken. Repeat sets of readings until certain of a set taken at the same line voltage.

TABLE II

$R_1 - R_5 = 99$	Volts
$R_1 - R_2 = 64$	"
$R_2 - R_3 = 18$	"
$R_3 - R_4 = 11$	"
$R_4 - R_5 = 6$	"
$R_1 - R_5 = 99$	"

Table II gives test readings taken from a Westinghouse coil after years of service. In this test an extra resistance of 18 ohms was connected in series with the coil, the line voltage being 495 volts.

62. *Note.* The drop across, hence the resistance of, the first section exceeds half the total drop of 99 volts. The drop on section 2 (R_2-R_3) exceeds half the drop from R_2 to R_5; and the drop on section 3 (R_3-R_4) exceeds half the drop from R_3 to the end of the coil—R_5; and so on.

63. Empirical Rule. Tests on numerous starting coils showed the resistance to be so distributed that notch 2 cut out more than half the total resistance and each succeeding notch cut out a little more than half the resistance in circuit immediately preceding the action of that notch.

64. *Remark.* In applying a voltmeter to determine the resistance distribution in a modern starting coil, If the drop on the first section exceeds half the total drop and the drop on each succeeding section slightly exceeds half the remaining drop, the resistance distribution may be considered good.

65. *Example.* A car equipped with 4 motors and K_6 controllers jumped badly on the sixth notch. What was the trouble?

66. *Solution.* On applying the voltmeter, the drops recorded were those of Table III. Noting

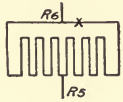


FIG. 17

that the drop from R_5 to R_6 was much greater than the drop on either side of it, a closer inspection was made and the trouble was found to be due to an open-circuit in one of the wires used to connect two parts of one of the resistance units

in parallel, as indicated in Fig. 17, where the open-circuit is marked x.

TABLE III

$R_1 - R_7 = 36.0$	Volts
$R_1 - R_2 = 17.0$	"
$R_2 - R_3 = 8.0$	"
$R_3 - R_4 = 5.0$	"
$R_4 - R_5 = 2.5$	"
$R_5 - R_6 = 3.5$	"
$R_6 - R_7 = 1.5$	"
$R_1 - R_7 = 36.0$	"

67. *Note.* On the older types of controller that had but 3 or 4 resistance notches, the second notch cut out considerable more than half the total resistance: thus on the K_2 controller, in conjunction with a three-section starting coil, the second notch cuts out two-thirds of the total resistance and the third notch cuts out two-thirds of the remainder. On controllers employing from 7 to 10 resistance notches, the second notch can cut out considerably less than half the total resistance, without any bad results.

68. Trial Notching. This consists in connecting the coil by guess, then operating the car to note its

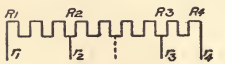


FIG. 18

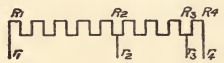


FIG. 19

action. Suppose, for example, that a three-section coil, Fig. 18, thus connected, causes a bad jump on the third notch. The figure shows that R_1 and R_2 are too close together. In some types of coil this

would not be so evident, as the coil might be composed of several frames, each containing several sizes of resistance grids. However, jumping on the third notch indicates too much resistance between R_2 and R_3, and too little from R_1 to R_2, moving R_2 near to R_3, as indicated by the dotted line, would stop the jump on the third notch but would tend to introduce it on the fourth, due to making resistances R_2-R_3 and R_3-R_4 too nearly equal, the former having been increased and the latter kept the same; this being the case, then R_3 could be moved toward R_4, the final connection being indicated in Fig. 19. This change might in turn cause a slight jump on the fourth notch, in which case R_2 would have to again be shifted a little and so on, a satisfactory arrangement being gotten only by repeated adjustment and trial.

CHARGED CONDITIONS

69. Insulation Test. A starting coil must have good insulation from the resistance metal to the containing frame and from the containing frame

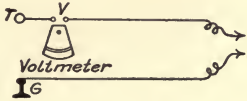


FIG. 20

to the iron parts of the car; otherwise, should the resistance metal become grounded to the frame, a grounded person touching an exposed iron part

would be liable to shock. The test is best made with the connections of Fig. 20, where T is the positive side of the circuit; V, the voltmeter; G, the negative side of the circuit and t and t', the meter and ground test lines respectively. The test can be made as follows:—

70. *Directions.* To test, with a voltmeter, the insulation resistance from the resistance metal to the frame of a starting coil, Hold t on the resistance metal, t' on the frame and note the deflection; to test the insulation from the frame to a car iron, hold t on the frame and t' on the car iron and note the deflection.

71. *Note.* In neither case should the insulation of an installed coil be passed if the deflection exceeds 250 volts on a 500 volt line, when the under side of the car is soaking wet.

72. Shock Test. Assuming that 50 volts applied to an average man will shock him sufficiently to cause him to fall: then further assuming that a 60,000 ohm voltmeter shows an insulation deflection of 250 from the frame to an iron car part, and that the resistance metal happens to be grounded to the containing frame; then under these conditions any one touching the exposed iron car part and the ground at the same time would be shocked. As the resistance of the person will be in series with that of the leakage path to the car iron, the voltage will divide between them in the ratio of their resistances. Assuming the resistance of a man, including the imperfect contacts that he may make with

the parts, to be 5,000 ohms and the leakage path to measure 60,000 ohms, the drop across it will be 12 times that across the man; the man, then, would be subjected to a voltage of one-thirteenth of 500 volts = 39 volts. Assuming a resistance value for the human body and knowing the value

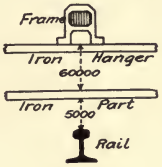


FIG. 21

of the line voltage and the resistance of the leakage path, the voltage to which a passenger is liable under assumed conditions, can be calculated as follows:—

73. *Rule.* To calculate the voltage to which a person will be liable on touching an exposed part fed through a leakage path of known resistance, from a line of known voltage, Multiply the assumed resistance of the human body by the line voltage and divide by the sum of the resistances of the body and the path.

74. *Example.* A passenger shocked on alighting from a car in motion was thrown and injured. Investigate conditions and determine the approximate voltage of the shock, assuming a body resistance of 4,000 ohms.

75. *Solution.* The car was turned in and repor-

ted as charged. Voltmeter tests showed that a live starting coil frame charged a bonnet stanchion which the passenger held after touching the ground. A voltmeter test showed a leakage path resistance of but 28,000 ohms, the maximum voltage at the locality in which the shock was received being 505 volts.

$4{,}000 \times 500 = 2{,}000{,}000$; $4{,}000 + 28{,}000 = 32{,}000$; and $2{,}000{,}000 \div 32{,}000 = 62+$ volts.

76. *Note.* The leakage path resistance can be measured as described in Art. 40, P. 51 of "*Shop Tests on Electric Car Equipment.*"

CAR LIGHTNING ARRESTERS

CONNECTION TESTS

77. Conventional Connection. A lightning arrester with a broken or loose trolley or ground wire is useless as protection. These connections should be tested periodically. In Fig. 22, T-M is the path from the current collector to the controller. The arrester, of which *a* and *b* are spark points, taps in

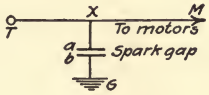


FIG. 22

at *x* and to ground at G. If *x* is on the car roof on the positive side of all switches and circuit breakers, it will be alive whenever the pole is on; but if on the controller trolley wire, one breaker or switch, if the two are in parallel, or both, if in series, must be closed, before the upper spark point of the arrester is alive.

78. *Directions.* To ascertain if the arrester trolley connection is intact, Ground one end of a lamp circuit and touch the other to the upper spark point. To ascertain if the lower spark point is grounded, Connect one end of the lamp circuit to trolley and touch the other end to the lower spark

point. In both cases, the lamps will glow if connections are intact.

79. *Note.* On arresters in which the car current traverses the blow-out coil, no trolley test is required, for an open-circuit would prevent the car from taking any starting current.

80. Actual Connection. Fig. 23 is a sketch of the internal connections of a much used type of arrester. Stretch of circuit T-M leads to the controller and includes fuse box FB; the arrester tap

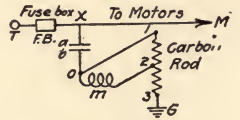


FIG. 23

is at x; the spark points are a and b; m, a magnetic blow-out coil; posts 1, 2 and 3 include a carbon resistance rod. A lightning discharge takes path a-b-o-1-2-3-G; the trolley current, which follows, takes the lower resistance path a-b-o-m-2-3-G, including the blow-out coil, which extinguishes the arc. A test can be made as follows:—

81. *Directions.* In testing an arrester for continuity, the continuity of the carbon rod is insured by inspection; with a test circuit, Test continuity from 0 to 1 and from 0 to 2.

82. *Note.* A break in 0-1 will make the arrester useless, for a lightning discharge will not traverse coil m. A break in 0-2 will disable coil m, in which

case a discharge would be likely to destroy the arrester.

83. Operating Test. The final test for arresters is to install them where lightning discharges are frequent and violent, see that they are kept adjusted and inspect them after each storm to note the condition of those that may have operated.

84. Arc Extinguishing Test. The effectiveness of the blow-out device in extinguishing arcs, can be tested as follows:—

85. *Directions.* To test the arc extinguishing effectiveness of an arrester blow-out device, Connect the arrester as in Fig. 24, where K is a circuit-breaker or switch; R, a resistance of one or two

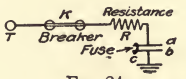


FIG. 24

ohms; *a* and *b*, the arrester spark points; *c*, a single strand of flexible lamp cord to serve as a fuse. On closing switch K, the melting of the fuse establishes an arc that the blow-out should break.

86. *Note.* Resistance R replaces the resistance ordinarily provided by the line and the track return, thereby limiting the short-circuit to actual working conditions.

87. Air-gap Adjustment. Where an arrester has an air-gap, it must be thinner than any equipment insulation to be protected, otherwise the lightning discharge is apt to puncture the insula-

tion of some expensive device instead of jumping the air-gap. The gap thickness used is 0.025 in.

88. *Directions.* To test or adjust the thickness of an arrester air-gap, Make a sheet metal gage 0.025 in. thick and of convenient size and shape to insert between the spark points. Apply the gage

Fig. 25

Fig. 26

as in Fig. 25 and not canted, as in Fig. 26, otherwise the real air-gap will be thicker than the apparent one.

89. *Note.* Some railway men doubt the effectiveness of car arresters, this skepticism being based on the failure of the arresters to save equipment. Failure is as often due to neglect as to inherent unreliability. One of the writers twice sat over arresters that operated effectively and has no difficulty in recalling the occasions.

CAR WIRING CABLES

PRELIMINARY CONSIDERATIONS

90. Cable tests include a preliminary determination of the manner in which the cable must be tagged to have the car respond correctly to the indication of the reverse switches on both ends; ringing out and testing for insulation and crosses.

91. Motor Rotation Test. This test is to determine the direction of armature rotation for given connections:—

92. *Directions.* To ascertain the direction of armature rotation for armature and field connections of given polarity, Connect a field and armature terminal together, ground one of the remaining terminals, connect the other to trolley, close the the circuit and note the direction in which the armature rotates, the observer facing the commutator end of the motor.

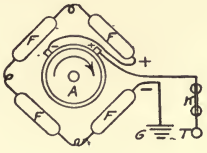


FIG. 27

Thus Fig. 27 shows that when the right hand brush-holder is positive the left hand holder negative, the top field lead positive and the bottom

206524

negative, the armature rotates in a clockwise direction on this particular motor. In any case the direction of car motion will be *opposite* to that of the top of the armature, because the axle and armature are connected by gear and pinion. In modern controllers, the single A's are positive and the double A's negative, the F's are positive and the E's negative. Thus A_1, A_2, F_1 and F_2 are positive; but AA_1, AA_2, E_1 and E_2 or G are negative. Only these have to do with direction of rotation.

93. Application of Data. Standing at the center of a single-truck car and looking toward either end, the commutator will be on the right. Viewing a motor from the commutator end, for it to move the car to the right or forward, the top of its armature must move to the left. As the axle is to the right, the motor leads will probably be brought out of the frame on the left. Fig. 27 shows them brought

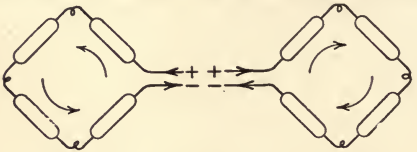


FIG. 28 FIG. 29

out on the right; the effect of such a change is to reverse the current in the field coils for given connections. In Fig. 28, when the top field lead is positive, the current around the field is counter clockwise; on changing the leads to the left and

keeping the top field lead positive, the current around the fields becomes clockwise as in Fig. 29. For the top of the armature to move to the left, then, the right hand brush-holder must be positive, so that the top field lead can be kept positive, a condition that lessens the liability of grounded field parts.

TAGGING AND INSULATION TEST

94. Tagging the Cable. Cable work in detail will be considered under another heading. Tagging is but a small part of it. For a two-motor car, employing a four-section starting coil, there will be trolley and ground wires; five resistance wires and seven motor wires, one field wire being in common with the ground wire. (On cars for a conduit system, the T_2 wire replaces the G wire and there is an extra E_2x wire running from one cutout-switch to the other making a total of 15

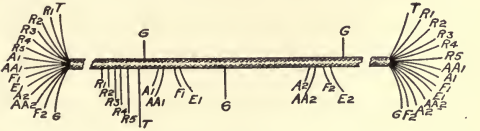


FIG. 30

wires.) Fig. 30 is a sketch of a completed cable, the two larger wires of which are trolley and ground.

95. *Directions.* To tag a cable, Tag one end of each of the larger wires T and G; then, with a test circuit, identify the other ends and tag them the

same. Next, identify the intermediate taps, of which there are three on G and one on T, and tag them the same as their corresponding through wires. Next, assuming all remaining wires to be of the same size, tag them successively, on one end, R_1, R_2, R_3, R_4, R_5. A_1 AA_1, F_1, E_1, A_2, AA_2, F_2 and E_2. Next, identify the opposite ends of each and tag them accordingly. Finally, identify the intermediate taps and tag them.

96. *Note.* Knowing the location of the starting coil and the order in which its terminals lie, the resistance tap wires are brought out and tagged in the same order to avoid crossing the taps under the car. The motor cable terminals, also, are brought out to be opposite the correct motor leads.

Where a number of cars are to be done, care in tagging the first cable will save much time in connecting the cars.

97. After the cable is tagged, the armature wires on the No. 2 end are exchanged, A_1 exchanging places with AA_1 and A_2 with AA_2. Unless this is done, the car will obey the indication of the reverse switch on one end but not on the other. Except where the cable men understand each other well, it is best to tag the wires straight and cross them afterward; sometimes the wires are tagged straight anyhow, the crossing being left to the wireman that connects the controllers.

98. Insulation Test. This test, made with a lamp or bell circuit, simply insures that no wire touches any other wire. On piped equipment,

the insulation test is made with high voltage (2,000) because a wire is liable to be snagged in drawing it through the pipe. Fig. 31 shows the connections for the test, the number of lamps in series depending on the voltage used. Test point *t* is attached to any wire and *t'* touched to all other wires,

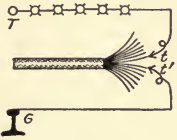


Fig. 31

this test being repeated until all wires have been tested together. Where the lamps indicate a contact, the involved wires may be found to be touching each other at the ends of the cable.

CAR MOTORS

BRUSH-HOLDER REQUIREMENTS

99. Brush Spacing. Brush spacing refers to the distance apart of the brushes on the commutator. Thus in Fig. 32, where *a* is one brush, *b* the other, *c*, the commutator, angular distance *d* is a fixed quantity and must be maintained if the

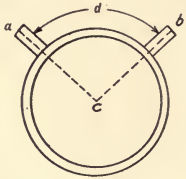


FIG. 32

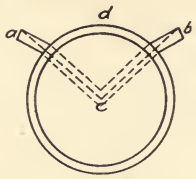


FIG. 33

motor is to operate sparklessly. The commutator bars are wedge-shaped and get thinner as the commutator wears; as the brushes remain the same thickness, the number of bars between inside brush edges is slightly less on a worn commutator than on a new one; but the number of bars between brush centers and the angular distance *d* do not change if the holders are correct in the first place.

100. Radial Alinement. As the commutator wears or is turned to smooth it, the feeding in of the brushes must be strictly radial, that is, the brush contact surfaces must move directly toward

the center of the commutator. Fig. 32 indicates strictly radial brushes; here the long axes of the brushes are continuations of the radii drawn to the centers of the brush contact surfaces. The brushes will set square with the commutator when installed and will wear square on the ends. Fig. 33 indicates brushes the contact surfaces of which follow commutator wear radially, but the axes of which are not radial, the ends being beveled to give greater contact surface without increasing the thickness of the brush. The requirement of such a brush is that the wearing surface shall feed radially although the brush does not.

101. Symmetry of Set. The brush-holder must primarily hold and maintain the brushes symmetrical in regard to a certain line passing through the center of the commutator. On most surface

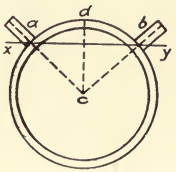


FIG. 34

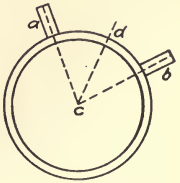


FIG. 35

car motors line *xy* Fig. 34, passing through the centers of contact of the brushes, is horizontal if the motor sits level; in such a case, the line of symmetry is vertical radius *dc*. On some of the larger motors used in high speed service, the motor

hand hole covers are set at an angle so that brush inspection and renewals can be made from the under side of the car without lifting trap-doors; the line of symmetry is not then the vertical radius, but some other radius the deflection of which depends on the angle of displacement of the hand holecover. In any case, angles *acd* and *bcd* must be equal or the brushes will spark in one or the other direction of rotation.

BRUSH-HOLDER IRREGULARITIES

102. Types of Holder. Brush-holder riggings are of either the independent type or the yoke type. In the former, the two holders are not mechanically connected:—most Westinghouse railway holders are of this type. In the yoke type, the two holders are supported by a wooden yoke:—most of the older holders of the General Electric Company are of this type. Most of the irregularities of the independent type are incident to carelessness or ignorance in repairs or installation:—The holder seats in the motor frame are babbitted with a jig, so that a correct holder properly installed cannot set the brushes wrong; but if holder seats are rebabbitted with a homemade jig that is in error, or if the holders be made of castings of varying shrinkages and, therefore, of uncertain dimensions, or if in installing the holder no care is taken that the holder guide surfaces register flush with the corresponding frame seats, the brush set is apt to be wrong. The yoke type is liable to the same irregu-

larities and in addition endless trouble can be started by using untreated, badly seasoned wood or yoke brackets of different heights.

103. Errors of Setting. Wrong brush set may be due to one or more of several conditions that will now be considered.

104. Wrong Brush Spacing means brushes too close together or too far apart; in either case there will be sparking, but more in the former case than in the latter. One brush may be in its right position, Fig. 36, but the other too far one way or the other:—the displaced brush will spark.

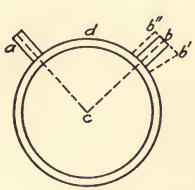


FIG. 36

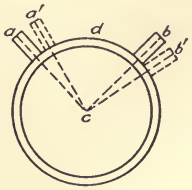


FIG. 37

105. Lack of Symmetry, that is, the brushes correctly spaced, so far as count is concerned, but both holders too far around in one direction or the other, Fig. 37, will cause sparking in one direction of rotation, but not in the other, because in one direction armature reaction reduces the sparking, but in the other aggravates it.

106. Lack of Radial Alinement, even with correct spacing and symmetry, will cause initial sparking, unless the brushes are sandpapered to fit the

commutator, and conditions will get worse with time. In Fig. 38, the brush axes point at c'—above the commutator center, so that wear will bring

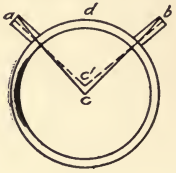


FIG. 38

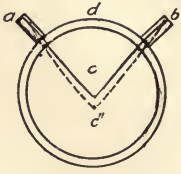


FIG. 39

them closer together and out of set. In Fig. 39, the brush axes point at c''—below the commutator center, so that commutator wear will force them further apart—a bad enough condition, but not as bad as the first.

107. Wrong Height of Bracket raises or lowers the holders vertically, according as the bracket is

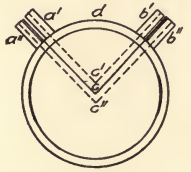


FIG. 40

too short or too long (see Fig. 40). With a short bracket, the brush axes will point above center and the brushes will close in with commutator wear. With a long bracket, the brush axes will

point below center and the set will spread with commutator wear. Defect in radial alinement differs from a bracket defect in that the former may correctly space the brushes initially, while the latter starts them off with incorrect spacing and maintains the condition.

108. Canted Brushes refers to the condition illustrated in Fig. 41(a), in which the brush is shown resting on one end corner. Under this condition the brush contact surfaces will wear to the shape indicated in Fig. 41 (b). On the inde-

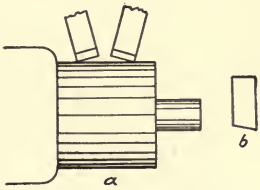


FIG. 41

pendent type of holder, this may be due to insulating washers of uneven thickness or to foreign matter behind them. If the brushes in both holders of the yoke type wear in this way, indications point to irregularity in the setting of the yoke itself, but it is possible for both holders to be in fault.

109. Wear in Armature Bearings lowers the commutator bodily, thereby causing holders, otherwise all right, to set the brushes too close together,

as shown in Fig. 42. The error may be small, but where the bearings are babbitted above center to increase the safe wear and to decrease the frequency of clearance inspections, the error, in conjunction with other errors, may be considerable. As motors

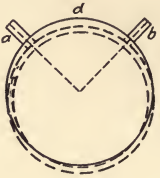


FIG. 42

spark less with brushes too far apart than with them too close together, it might be well to so design holder riggings as to initially set the brushes a little too far apart, to allow for the effect of bearing wear.

110. Brush Pressure. By brush pressure is meant the force with which the brush is pressed down by the brush-holder spring.

111. Pressure Requirements are varied; more pressure is needed on rough track or at high speed than on smooth track or at low speed; some qualities of brush require more pressure than others. With deficient pressure, rough track or commutator will cause the brushes to jump, thereby producing bad sparking and liability to flash over. Excessive pressure subjects both commutator and brushes to excessive wear. Between these limits

wide variations exist, even on motors from the factory.

To reduce pressure comparisons to a common basis, the pressures must be expressed as so many units of force per unit of contact surface. The units used in this country are pounds or ounces per square inch. The brush pressures on surface car motors vary from 2 to 6 lb. per square inch.

112. Pressure Tests consist in actually applying a scale to determine the total brush pressure on the commutator. In applying the scale, the reading must be taken when the scale and brush axes are in line as in Fig. 43, where the correct pull is

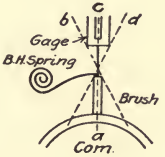


FIG. 43

indicated along line *ac;* a reading taken in any other direction, such as *ab* or *ad*, will not be a true one. If the pressures are to be measured on installed holders, and the motor shells prevent a direct pull on the scale, a smaller scale must be obtained or a rigging similar to that of Fig. 44 used. Here the scale connects to a lever at its middle point, the end *o* engaging the brush finger as near to the brush

as practicable. The test is applied and calculated as follows:—

113. *Directions.* To test brush pressure with a spring scale, Hold the scale in one hand, the end x, of the lever in the other; pull on the scale and push on the lever, keeping the axis of the scale at right angles to that of the lever; just as the brush finger leaves the brush, read the scale. To get the total brush pressure in pounds, divide the scale reading by two.

114. *Note.* Were the scale applied directly to the finger, the reading would be direct; but as the pull is applied to the middle of a lever, the ends of which are supported by two equal pulls, the scale reading must be divided by two.

115. Expressing the Pressure is now a matter of determining the area of the brush contact surface in sq. in., then dividing the total pressure by the area to get the pressure per sq. in. The surface area can be calculated as follows:

116. *Rule.* To get the area of a brush contact surface in square inches, Multiply the length and breadth of the contact surface in inches; the result will be the contact area in square inches.

117. *Example.* The contact area of a G.E.57 brush measures $\frac{5}{8}$ in. by $1\frac{3}{4}$ in. Find the contact surface area in square inches.

118. *Solution.* $\frac{5}{8} \times 1\frac{3}{4} = \frac{5}{8} \times \frac{7}{4} = 1\frac{3}{32}$ sq. in.

119. *Note.* Except where the contact surface is beveled, as in the case of the G.E.800 brush, the

brush width, multiplied by its thickness, gives the area of the contact surface.

Having the area of the contact surface and the total brush pressure, the pressure per square inch is calculated from the following:

120. *Rule.* To get the brush pressure per square inch, Divide the surface contact area in square inches by the total pressure in pounds.

121. *Example.* The contact surface area of a G.E.57 brush is $1\frac{3}{32}$ sq. in. and the total pressure 9 lb. What is the brush pressure per square inch?

122. *Solution.* $9 \div 1\frac{3}{32} = 9 \div \frac{35}{32} = 9 \times \frac{32}{35} = \frac{288}{35} =$ 8.23 lb. per sq. in.

MISCELLANEOUS BRUSH TOPICS

123. To conclude the brush-holder subject, distance from commutator, counting off brushes and the importance of brush-holder maintenance will be considered.

124. Distance from Commutator refers to the clearance between the lower end of the holders and

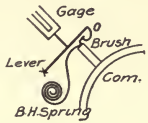


FIG. 44

FIG. 45

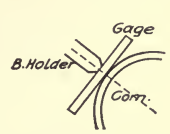


FIG. 46

the commutator. If this distance is excessive, the brushes are apt to shift positions when the direction of motion of the car is reversed, and develop

two wearing surfaces, as indicated in Fig. 45. The same condition will obtain if the brush is too thin or the brush-way too large. If the holders sit too close to the commutator, dust and oil are apt to gum up the clearance and cause sparking. The proper clearance is about $\frac{3}{16}$ in. and this clearance should be insured by applying a gage as in Fig. 46, the gage being tapered a little to facilitate withdrawing it.

125. *Note.* To insure uniform dimensions of brushes, they should be passed through limit gages and the extra thin and thick ones rejected. In installing brushes, they should be inserted from both ends to see that one end is not thicker than the other, because if this is the case and the brush is inserted thin end first, it will stick when the thick part reaches the brush way and trouble will follow.

126. Counting Off Brushes consists in counting the number of commutator bars included in the brush spacing. Counting bars is easier than measuring distance in a hot motor. A draughtsman will count brush set from the center of contact of one brush to the center of contact of the other, because he has the drawing where he can get at it; the car-house-man, however, can not conveniently locate the centers of contact, because shadows and the lower end of the holders obscure them; so he counts the bars included between the inside edges of the brushes, as indicated in Fig. 47, where both the center to center and inside counts

are shown. Knowing the number of commutator bars and the number of motor poles, the center to center count is gotten from the following rule:

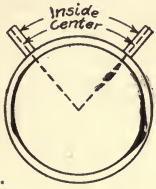


FIG. 47

127. *Rule.* To get the center to center count of the brushes on a railway motor from the number of commutator bars and motor poles, Divide the number of commutator bars by the number of motor poles.

128. *Example.* A Westinghouse No. 101 motor has 111 commutator bars and 4 motor poles. What is the center to center brush count?

129. *Solution.* $111 \div 4 = 27\frac{3}{4}$ bars.

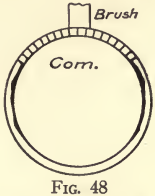


FIG. 48

130. Deriving the Inside Edge Count from the center to center count requires that one of the

brushes be applied to a commutator, as indicated in Fig. 48, to determine how many bars are spanned by the thickness of a brush. With this information, the inside count can be derived from the center to center count, by the following rule:—

131. *Rule.* To get the inside brush count of a railway motor from its center to center count, Subtract from the center to center count the number of commutator bars spanned by the thickness of one brush.

132. *Example.* The center to center count of a Westinghouse No. 101 motor is $27\frac{3}{4}$ bars; the brush spans $1\frac{3}{4}$ bars. Wanted, the inside edge count.

133. *Solution.* $27\frac{3}{4}$ bars $-1\frac{3}{4}$ bars $=26$ bars.

134. The Importance of Brush-holder Maintenance can not be exaggerated. Considerable space has been given to brush-holders and their irregularities and more could be devoted to the subject if it could be included in a testing book of limited scope:—armature endplay, crooked holders, maintenance and desirability of shunts, freedom of moving parts, etc., could well be discussed. The only way to maintain brush-holders and parts is with suitable jigs and efficient inspection. The introduction of jigs on a large road reduced the number of brush-holder repairmen from 4 to 1; this represented but a small economy as compared with the saving in the handling and repair of other equipment parts affected by sparking due to faulty brush-holder conditions. This device is more

abused and neglected through ignorance, indifference and carelessness than other parts able to take care of themselves. Did brush-holder irregularities affect only the holders, overlooking their welfare would not be so serious; but when one realizes that a faulty holder may burn a string-band, loosen the head, break a band-wire and either burn out the armature or grind it to a condition of uselessness, or both, the impression is gained that this important device should be made and maintained with care rather than with "licks and no promises."

MOTOR INSULATION TESTS

135. Armature Insulation. To test the insulation of an armature on the floor, use the connections of Figs. 36–37, "*Shop Tests on Electric Car Equipment.*" For an installed armature, the same connections are used, but the motor brushes must be drawn, otherwise it will not be known whether a possible ground is on the armature or on some connected device.

136. Field Coil Insulation. On uninstalled field coils devoid of containing shells, there is no surrounding metal to which insulation can be tested; if such a coil has been grounded it will show it. If the coil is installed or has a containing shell, the connections referred to in Art. 135 can be applied as follows:—

137. *Directions.* To test field coil insulation in the motor, Disconnect the field leads and axle jumper and test to find in which half the fault lies;

the faulty pair located, inspect to see if the trouble may be a terminal or connecting jumper that can be fixed without opening the motor; if on opening the motor the fault is not evident, separate the field coils and test them separately to locate the faulty one.

138. Brush-holder Insulation. With the ordinary lamp test circuit, brush-holder insulation can be tested as follows:—

139. *Directions.* To test brush-holder insulation, Draw the brushes, disconnect the brush leads and test between holders and from each holder to the motor frame.

140. *Note.* Complete carbonization of the under side of a yoke may exist, in which case it cannot be seen from above but can be felt with the hand.

MOTOR CIRCUIT TESTS

141. Open-circuited Field Coil. As a 2-motor car with an open-circuited field coil cannot start on a series notch, the faulty motor must be located either by throwing the controller to parallel and noting which motor works, or by trying the motors one at a time. Inspection may reveal a disconnected lead or axle jumper; if not, the bell circuit test can be applied as follows:—

142. *Directions.* To test for open-circuit field with a bell circuit, Disconnect the field leads and see if the bell will ring through from one lead to the other; if not, disconnect the jumper and test top and bottom pairs separately; if inspection shows that the motor most be opened, do so and

test one field coil at a time until the faulty one is located.

143. Open-circuit and Grounded Coil. A special case of open-circuit field coil is where a connecting wire burns off and welds to the frame, as indicated in Fig. 49. If on motor No. 2, the car will operate, but the faulty motor will spark. A bell circuit

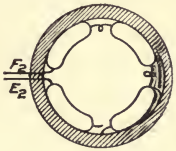


FIG. 49

applied to F_2 and E_2 would indicate an open-circuit, because a bell circuit has no ground connection. A lamp test would not indicate an open-circuit unless the ground end happened to be applied to F_2 and the trolley end to E_2; with the trolley applied to F_2, a ground would be indicated. On getting an open-circuit indication with t on E_2 and a ground indication with t on F_2, the true condition would be suspected. Combination faults, consisting of two or more faults, give much trouble.

144. Open-circuit Armature Test (first method). From brush to brush, a railway motor armature has two paths, so that an open-circuit in one does not open the circuit. One symptom of such a fault is a flash around the commutator when the car is run on both motors or is run down hill on the

faulty one. On a level, the motor will start if the armature happens to be in a favorable position when the current is applied, but will tend to act in impulses.

145. Open-circuit Armature Test (second method). A direct test for armature open-circuit is to measure its resistance by one of the methods given in "*Shop Tests on Electric Car Equipment.*" From brush to brush, an open-circuit railway armature will measure twice its normal value.

146. Open-circuit Armature Test (third method). A test for open-curcuit in an armature can be made with a voltmeter as follows:—

147. *Directions.* To test an installed armature for open-circuits, with a voltmeter, Connect the

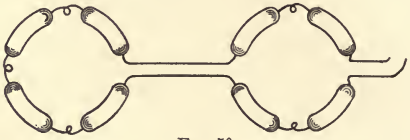


FIG. 50

field-winding of the faulty motor in series with that of the good motor, as indicated in Fig. 50, so that when the car is operated the field of the faulty motor becomes separately excited. Next, hold the test lines from a voltmeter on the brush-holders of the suspected armature and note the action of the voltmeter needle when the car is operated:—with an open-circuit in the armature, the voltmeter needle will wave to and fro.

148. Open-circuit Armature Test (fourth method). Fig. 51, a diagrammatic sketch of a ring winding, shows that a single open-circuit, as indicated at x does not divide the winding into two isolated sections, but that if another open-circuit, as indicated at y, be created, the winding is divided into two sections that will not ring up together,

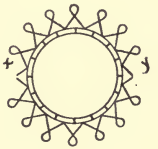


FIG. 51

when one test point of a bell circuit is touched to one section and the other to the other section of the winding. An uninstalled, suspected armature can, then, be treated for an open-circuit as follows:—

149. *Directions.* To test an armature for open-circuit, Create an open-circuit by disconnecting one coil lead; then, holding one test point anywhere on the commutator, pass the other around the commutator:—If a faulty open-circuit exists, there will be certain bars on which the test lamps will fail to glow when the free test point is applied to those bars.

150. Short-circuited Field Coils. If the field coil terminals can be bared, or if the voltmeter test lines are provided with sharp awls with which

to pierce their insulation, a faulty field coil can be located with a voltmeter as follows:—

151. *Directions.* To locate a short-circuited field coil with a voltmeter, Connect an extra resistance of 20 or 25 ohms in series with the motor circuit, set the brake, pass a current and take the drop on each coil with a low reading voltmeter; a faulty coil will give a lower drop than a standard coil.

152. *Note.* Should all coils give the same drop, all are either good or are equally bad; to ascertain which, Connect a standard coil in series with them and compare their drops with that gotten on the standard coil with the same current.

153. Short-circuited Armature. When the car is run on both motors, the short-circuited armature will operate in jerks; this action is intensified by running the car down hill on the faulty motor alone; also, one or more coils will heat much more than others. Even if the fault includes but little of the winding, if a knife be held near the head of the armature while taking current with the car in motion, the knife will pulsate in a manner quite distinguishable from the more rapid vibrations due to the field magnetism whipping from one tooth to the next.

154. Grounded Armature. A grounded armature acts similarly to a short-circuited one, but tends more violently to lock in certain positions of its rotation. A ground on armature No. 1 will prevent starting with current, unless the armature

happens to lie in a position where the effect of the fault is a minimum; in this case, the car will move a little and stop, blowing a fuse or breaker, should the controller be advanced sufficiently far. With the ground on armature No. 2, the car will operate in series on No. 1, but the faulty armature will turn in jerks and the fuse will blow on a parallel notch.

FIELD COIL POLARITY TESTS

155. Nail Test. The nail method of testing the polarity of installed field coils is given in "*Shop Tests on Electric Car Equipment*," Art. 72, p. 86, and need not be repeated here.

156. Compass Test (first method). Owing to magnetic leakage, a compass can be externally applied to determine if installed fields are properly connected. Fig. 52 is a section through the poles

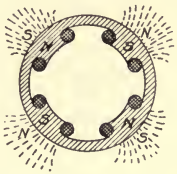


FIG. 52

of a motor and shows the internal poles, each with its external pole due to magnetic leakage in directions indicated by the dotted lines. With correctly connected coils, the internal and external poles

will alternate in polarity. With an ordinary pocket compass, that costs 50 cents, the test can be made as follows:—

157. *Directions.* To test field coil polarity externally and with a compass, Connect a resistance of 20 or 25 ohms in series with the motor circuit, set the brake and block the car-wheels; pass the compass around the motor: with proper field connections the needle will reverse at each pole. If 3 poles are alike, the middle one holds a wrongly connected coil; if there are like pairs on a side or above and below one pole of each pair holds a wrongly connected field coil.

158. *Note.* Some skill is at first required to keep the compass needle from sticking, but this is soon overcome.

159. *Note.* If the motor is first subjected to full load current while standing, the current being then thrown off, the test can be made without current, owing to strong residual magnetism.

160. Compass Test (Second Method). Bought field coils may come wound in the wrong direction or with the ends connected to the wrong lugs; such coils sent out and installed bring on a lot of trouble before the cause is suspected. Electrically, the result is the same as connecting the coils wrongly in a motor, but the fault is worse because it is not evident to inspection. In modern motors all field coils are alike in like motors. All standard coils being alike, uninstalled coils of wrong polarity can be detected by the following test:—

161. *Directions.* To test the polarity of uninstalled field coils with a compass, Arrange on the floor and connect in series a standard coil and the coils to be tested, all being similarly placed. On passing current and moving the compass before

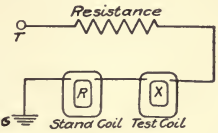


FIG. 53

the coils from one to the other, the needle will reverse in front of any coil of wrong polarity. The arrangement of coils is indicated in Fig. 53.

CARBONIZED FIELD COILS

162. Introductory Remarks. It is easy to devise a test to indicate a bad coil or a perfect one, but intermediate stages are hard to indicate with certainty without inspection.

163. Resistance Test. A fairly well baked coil can be detected by measuring its resistance. In measuring installed coils, the pole-pieces must be drawn tight to compress the coil and bring its convolutions together as they are when expanded by heat in service. Often, owing to shrinkage of the field insulation, this cannot be done without loosening the pole bolts and slipping split insulating washers behind the coils to take up the clearance. In bench testing, metal clamps must be

made, Fig. 54, to hold the coils while compressing them in a vise. Their resistance is measured while they are under compression. Any coil measuring 5 per cent. less than standard, is set aside to be inspected. The outer layers may be normal and the inner ones browned; or the outer layers

FIG. 54

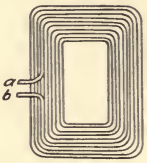


FIG. 55

may be light brown, too good to scrap, and the inner ones what the winder calls "rotten." The outer layers are exposed by removing the outer insulation; but to inspect the inner layers, the coil must be carefully opened.

164. Combination Test. The resistance test in conjunction with a voltmeter test, now to be described, is used for acquiring data sufficient to decide between a good coil and a bad one, and without ripping the coil apart for inspection. The combination test is conducted as follows:—

165. *Directions.* To apply the combination data test to field coils, Tag each coil with a number and pile them with No. 1 on top. One at a time and with the same current, take the drops on each

coil, carefully noting the drop opposite the number of the coil that produced it; the drops on all coils are then compared with the drop on a standard coil at the same current; next, remove the outside insulation being careful to replace any tags that may be torn off. Pull out the middle wire of the wide side of each coil, as indicated in Fig. 55, and cut it; this divides the coil into 2 parts, the turns of which lie close together in the center, where carbonization is most intense. Again place the coils under compression and, with a voltmeter, get the insulation deflection between ends *a* and *b*, in each case writing the deflection opposite the number of the coil from which it was gotten. Next, pick from the list pairs of coils that have given the same drop and deflection and also all coils the drops and deflections of which, could not be paired, open the coils, inspect them, and, in a fourth column, note the condition of the worst part of the coil, in each case being careful not to put the condition of one coil down on the sheet opposite the number of another coil.

TABLE IV

Coil No.	Drop	Deflec.	Remarks
1	10	200	Slightly browned but tough.
2	6	450	Almost black and very crumbly.
3	1	500	Rotten.
4	11	10	Perfect.
5	9	250	Dark straw, crumbly.

166. Record of Test. Table IV shows the method of tabulating the readings and making the notes. On comparing the resistance drops in the second column with the insulation deflections in the third column, it will be noted that a low drop corresponds to a high deflection and vice versa, because a low drop means poor insulation and so does a high deflection. Some coils may show a low drop and no deflection; in such a case investigation will show that the coil either is short on turns or is wound with too large a wire. All coils proven to be reclaimable, can be fixed, if they have been handled carefully, the cut wire being spliced with a copper sleeve. After the desired information has been gotten for each type of coil in service, the test record is kept for reference; after a perfect line has been gotten on the relation between the resistance of the coil and its condition, as revealed by the voltmeter test, it will be unnecessary to open the coil, as the resistance drop with the coil under known compression shows its condition.

ARMATURE CLEARANCE

167. Introductory Remarks. Except for an armature occasionally "getting away from the inspector" or a bearing giving trouble that could not be foreseen, there is no excuse for armatures rubbing the pole-pieces. With good lubrication $\frac{1}{16}$ in. of babbitt will last at least two months:—armatures do not go down on the pole-pieces in unguarded moments, but rather as the result of unguarded weeks.

168. Preliminary Symptoms. One of the first symptoms of low bearings is difficulty in keeping lubricant in the grease boxes. Even slight rubbing acts like a brake on the core, heating the motor mechanically by friction and electrically, because of the greater current required to overcome the friction of the rubbing core; the increased temperature of the motor thins the lubricant and it runs through, precipitating a hot box. This heated condition is sometimes called "a hot motor."

169. As the core lowers still more, the friction increases and the car breakers begin to blow, the friction finally becoming sufficiently great to lock the armature or to burn it out.

170. Inspection by Light. Most clearance inspections are made at night,—not the best time in the world for any inspection. Modern motors have front and rear hand-holes in line with the lower air-gap of the motor. If the eye be applied to the front hole while a light is held opposite the back hole, the clearance can be judged, although an inexperienced man may be confused by a peculiar perspective effect due to shadows.

171. Inspection by Gage. Gage inspection consists in shoving strip fiber between the poles and

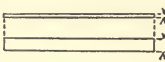


FIG. 56

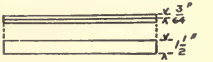


FIG. 57

core to test the clearance. The gage may be a single piece of minimum thickness, as in Fig. 56,

or it may be several pieces one of which is of minimum thickness, as in Fig. 57. The first type is the simplest, but the second has the advantage that an approximate idea of the thinness of the gap is given, even when the gap is not too thin. In either case, if the minimum thickness jams when shoved between the pole and core, the car should be "held in."

172. *Note.* A marked wedge-shaped gage has been suggested, to be applied at the front end of the air-gap. As the front clearance may be good, while the back clearance, where greater bearing wear obtains, may be bad, the straight gage that is shoved through to the rear end is to be preferred.

173. Inspection by Schedule. This means the appointing of certain days on which certain cars are to be inspected. The method has the advantage that the car is held for a specified object and under this condition the object is likely to be accomplished. Where lubrication is systematic and effective, the method is a good one, otherwise not.

174. Conclusion. Armature rubbing is generally attributed to the lower pole-pieces, but this is not always the case. Worn housings or eccentric bearings may permit the core to be drawn against the top pole-pieces. Loose top pole-pieces or projecting laminations or beads, due to former short-circuits, may be responsible for rubbing in the upper air-gap.

175. Considerable space has been given to *armature clearance*, but too much could not well

be given. Inasmuch as increased air-gap thickness decreases the effect of armature reaction, thereby decreasing sparking, and greatly reduces the most expensive of operating troubles—rubbing, it would seem that designers might well make sacrifices in other respects and put out motors with air-gaps sufficiently thick to survive the average system of armature clearance neglect.

PART II—MOTION TESTS

MOTOR BALANCE TESTS

VOLTMETER METHOD

176. Introductory Remarks. Balance tests are made to see that the motors on a given car are electrically and magnetically balanced, so that they will divide the load equally. If two motors are balanced, voltage applied to them connected in series, will divide equally between them, because as their counter e.m.f.s and ohmic resistances are equal, so are their effective resistances; and as voltage distribution in a series circuit is the same as that of the resistance, the drop across one motor will equal that across the other. Also, with the motors in parallel, the current will divide equally between them, because the effective resistance of each of the independent motor paths is the same. Great difference in the distribution of voltage or division of current may be due to any of the following conditions:—

1. Open motor frame.
2. Baked, short-circuited, wrongly connected or grounded field coils or coils with the wrong number of turns;—all of these irregularities weaken the field magnetism, decrease the counter e.m.f. and lessen its ability to regulate the current.

3. Dissimilar armatures (one a three-turn and the other a four-turn, for example) will unbalance the counter e.m.f.s and cause unequal sharing of load.
4. A difference in the sizes of the pinions, gears or wheels will, by affecting the armature speeds, unbalance the counter e.m.f.s.
5. Wrongly set brushes, by changing the effect of armature reaction, unbalance the motors. The existence of several of these conditions, to a small degree in each case, will materially affect the balance and it may be hard to locate the most responsible cause.

177. Two-motor Car. Fig. 58 is a sketch of the current path on a two-motor car with the motors in series. Voltmeter V_1 is connected across No. 1

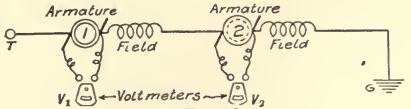


FIG. 58

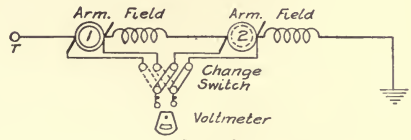


FIG. 59

armature and V_2 across No. 2. A single voltmeter can be used with a change-over switch, as indicated

in Fig. 59, but this has the objection that simultaneous readings cannot be taken.

178. *Directions.* To conduct a voltmeter balance test on a two-motor car, Run the car onto a level track or uniform grade, 300 ft. long. With motors in full series, when the speed becomes uniform, as indicated by the sound of the gears or by the steady needle of an ammeter placed in circuit for that purpose, read both meters; assuming the meters to be correct, if their readings are equal, the motors are balanced.

179. *Note.* If one meter indicates over 10% more than the other, conditions must be investigated by inspection.

180. *Note.* The sum of the readings cannot equal the voltage of the line, because fields, car-wires and contacts have resistance through which there will be some drop. On a number of cars tested at an average of 500 volts, each motor averaged from 235 volts to 240 volts. In one case one meter read 200 volts and the other 270 volts—a difference of 35%. The motor with the lower voltage was found to have carbonized field coils.

181. *Note.* To tell if the difference in the readings exceeds 10 per cent, the per cent. difference can be calculated as follows:

182. *Rule.* To calculate the per cent. difference in the readings of two meters, Divide the difference in the readings by the smaller reading, then multiply by 100.

183. *Example.* In a balance test, one meter read 200 volts and the other 270 volts. What is the per cent. difference in these readings?

184. *Solution.* $270-200=70$; and $70\div200=0.35$; and $0.35\times100=35\%$.

185. Four-motor Car. Fig. 60 indicates the current path through the motors on a four-motor car, with the controller in full series. Here two motors are paired in parallel and the two pairs are in series. Balance readings would not be taken under this condition, for there would be no direct way of

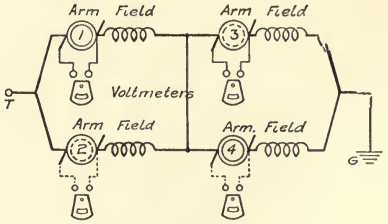


FIG. 60

telling to which motor a low reading might be due. Accordingly, one of each parallel pair is cut out and the test made on the remaining pair in series.

186. *Directions.* To make a voltmeter balance test on the motors of a four-motor car, Draw the brushes on one of each of the parallel motors; then make the test as on a two-motor car.

187. *Note.* Assuming motors 1 and 2 to be on one truck and 3 and 4 on the other, Draw the brushes

on 1 and 3 and test 2 and 4; then draw the brushes on 2 and 4 and test 1 and 3.

LAMP CIRCUIT METHOD

188. Two-motor Car. The lamp circuit test depends on the same principles of voltage distribution as the test just described; lamp circuits are used instead of meters. The number of lamps to be connected in series in each test circuit depends on the voltage of the line and on the rated voltage per lamp.

189. *Rule.* To find the number of incandescent lamps to be used in series on a line of given voltage, Divide the line voltage by the voltage rating of the lamps to be used.

190. *Example.* How many 50-volt lamps can be safely used in series across a 750-volt line?

191. *Solution.* $750 \div 50 = 15$ lamps.

192. *Note.* Where the line voltage is not exactly divisible by the lamp voltage, use the next higher number of lamps.

193. *Note.* The lamp test will indicate discrepancies due to wrongly connected, grounded, short-circuited or badly roasted fields, but will not indicate slight roasting or brush error.

194. Assuming 500 volts on the line and two test circuits of five 100-volt lamps each, a lamp circuit balance test is as follows:—

195. *Directions.* To make a balance test with lamp circuits, Operate the car as directed in Art. 177 and with lamps connected as in Fig. 61; if

the motors are approximately balanced all lamps will glow alike; should one circuit glow brighter, interchange the test circuits to see that the difference is not in the lamps themselves; if the same motor now causes the brighter circuit, the dimmer circuit indicates an irregular motor to be investigated. With a field coil connected backward or

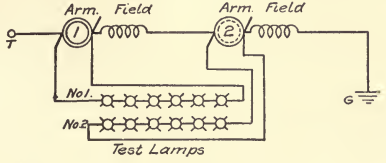


FIG. 61

with roasted fields, the lamps on the good motor will glow to almost full brilliancy, while those on the bad motor may not appear to glow at all. To make more decided indications, Unscrew a lamp in the dim circuit, drop a cent in the socket and replace the lamp. Repeat this short-circuiting of the lamps until the dim circuit glows.

196. *Note.* By using 50-volt lamps and changing the number in the test circuits until all glow alike, the voltage across each motor can be approximated by the following rule:—

197. *Rule.* To find the voltage per motor in a balance test from the number of lamps lighted to equal brightness and the total voltage across the two motors in series, Divide the total voltage across

the motors by the number of lamps to get the voltage per lamp, and multiply by the number of lamps on each motor.

198. *Example.* In a balance test, all lamps glow alike, one of the motors lighting five and the other, three. If 470 volts act across the two motors, what is the voltage across each motor?

199. *Solution.* $470 \div 8 = 59$; $5 \times 59 = 295$, the voltage acting on one motor. $59 \times 3 = 177$, the voltage across the other.

200. *Note.* If all lamps glow at full brilliancy, then, to get the voltage per motor, Multiply the rated voltage of one lamp (marked on its base) by the number of lamps on the motor.

201. Four-motor Car. The connections for the lamp test on a four-motor car are those of Fig. 60, except that lamps are used instead of meters. The test is conducted in the same manner.

AMMETER METHOD

202. Introductory Remarks. Ammeters, or their equivalent, can be used to determine the current division between two motors in parallel. Voltmeters cannot be usefully applied to the motors in parallel, because their voltages are then necessarily the same, although their current may be different; nor can an ammeter give useful information when the motors are in series, the current through them then being the same, although their drops may not be.

203. Two-motor Car. The connections for an

ammeter test on a two-motor car are given in Fig. 62; a meter is cut in with the field lead of each motor, care being taken to connect the positive side of the

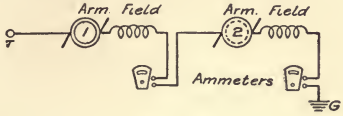


FIG. 62

meter with the positive side of the circuit. When the motors are in series, then the meters are also in series, and, if correct, will indicate the same current. On throwing the motors to parallel, however, each motor will include a meter that will indicate the current of only that motor; assuming the meters to be correct, if they then indicate equal currents, the motors are balanced; if the difference in the readings exceeds five per cent. of the lower reading, however, the cause must be located and removed.

204. *Note.* Except on cars equipped with interpole motors, the meters should not be cut into the armature leads, because ordinarily the car is reversed by reversing the armature currents and the meter deflections would reverse with them. Also as the armature wires are reversed in the No. 2 controller, a meter would deflect properly when operating from one end of the car but not from the other.

205. *Note.* An exception is made of interpole motors, because here the fields are reversed instead of the armatures.

206. Four-motor Car. Where four ammeters are available, it is well to cut a meter in with each motor, otherwise the motors must be tested in pairs; in this case it will not be necessary to draw any brushes, because on all parallel notches the motor paths are independent, each meter indicating the current of the motor with which it is in series. To check results, the motors can be tested in several combinations of pairs:—1 and 2; 1 and 3; 1 and 4; 2 and 3; 2 and 4 and 3 and 4.

MILLI-VOLTMETER METHOD

207. Introductory Remarks. Milli-voltmeters, or low reading voltmeters can be used for making a balance test. When so used, the instruments really constitute ammeters. With a 50 or 75-volt voltmeter, the motor field coils can be used as the standard resistances with which to connect the meters in parallel; but in this case, the coils, the drops on which are being compared, must have equal resistances. Where milli-voltmeters are used, equal lengths of the same size of copper wire will do for standard resistances. The main precaution is to see that no meter is subjected to a voltage exceeding its capacity. (See Art. 55, page 70, "*Shop Tests of Electric Car Equipment.*")

208. Two-motor Car. The connections for a milli-voltmeter balance test on a two-motor car, are given in Fig. 63. Cut into the field jumper of each motor (see Notes 205 and 206), is a piece of copper wire sufficiently large to carry the current

without heating and of such resistance that maximum current will not produce a drop exceeding the range of the meter to which it is connected as indicated. Either the current values of corresponding deflections must be ascertained, or the values of resistances r and r' must be different and such that equal deflections on the meters have the same cur-

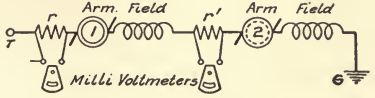


FIG. 63

rent value. With similar instruments or with their deflections adjusted to have equal values, the deflections are simply compared when the car operates at uniform speed with the motors in full parallel. If the difference in their deflections exceeds five per cent. of the lower deflection, the conditions must be investigated.

209. Four-motor Car. The test on a four-motor car is the same as the preceding, except that the meters and their shunts are to be applied to two motors at a time.

210. Current Values of Deflections may be required. As a deflection is due to a drop caused by motor current, each deflection corresponds to a certain current in the motor with which the meter is used. The determination of the values of meter deflections is called *calibrating* the meter.

211. *Directions.* To calibrate dissimilar milli-

voltmeters so that the readings on one can be understood in terms of the other, Connect a variable resistance, R, Fig. 64, an ammeter, and the two milli-voltmeters with their shunts properly paired, in series. Adjust the current until the lower reading milli-voltmeter deflects a maximum, noting the readings of the higher reading milli-voltmeter and ammeter. Calling the ammeter A, the higher reading milli-voltmeter B and the lower reading

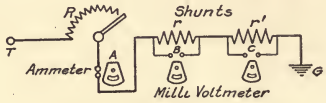


FIG. 64

milli-voltmeter C, when A deflects 60, suppose B to deflect 60 and C 100 divisions; then 1 division on B means 1 ampere and 1 division on C, $\frac{3}{5}$ ampere. In using the meters, B can, then, be read directly, but the deflections of C must be multiplied by $\frac{3}{5}$ to get their values in amperes.

212. *Note.* The readings are taken during the test and necessary reductions made afterward.

213. Adjusting Meters to Read the Same, consists in changing the resistance of r or r', Fig. 64, until given current produces the same deflection on both milli-voltmeters.

214. *Directions.* To adjust two milli-voltmeters to read the same for given current, Vary the length, hence resistance, of either shunt, until both milli-voltmeters deflect the same.

215. *Note.* It is advisable to so adjust the shunts that the whole scale of the lower reading instrument may be available because they will then be read more accurately.

216. Adjusting Meters to Read Direct, a refinement of the preceding adjustment, consists in varying r and r', until each of the milli-voltmeters deflects one division per ampere on A.

217. *Directions.* To adjust two milli-voltmeters to read direct, with the connections of Fig. 64, Repeatedly open the circuit, change the length of r or r', close the circuit, note the deflections of all meters and get the values of r and r' such that with a current of 50 amperes on the ammeter both of the milli-voltmeters deflect 50 divisions on their scales.

218. *Note.* Milli-voltmeters can be bought with shunts for direct current readings. A meter adjusted to read direct with one shunt will not, however, read direct with another shunt.

219. Use of a Change-over Switch, except in extreme cases, is to be avoided; where but one

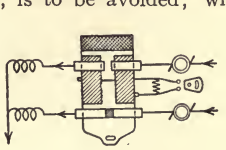


FIG. 65

ammeter or milli-voltmeter is available, however, a double-pole, double-slide switch, K, Fig. 65, can

be made to throw the meter from one motor circuit to the other without breaking the circuit of either. The ammeter or the milli-voltmeter and its shunt are connected across the centers of the switch, the end connecting posts being cut into the respective motor circuits. With the slide in the position shown, the meter is cut in with the No. 1 or upper motor; by throwing the slide down, the instrument is transferred to the other motor circuit.

VALUE AS A FIELD TEST

220. The voltmeter balance test is well adapted to finding baked field coils. Where the coils in both motors have weakened at about the same rate, the value of the test, as ordinarily made, is a minimum; but uniform deterioration of all the coils of a car, while possible, is a rare exception. The possibility of this condition is but the greater reason for occasionally giving motors new sets of coils to be tested against fields that long service may have deteriorated. Such a test could well be made by installing a newly equipped motor on a truck to be towed by any car having suspected fields. During a test, the towed motor would be connected in series with the car motor circuit, the drops on all three armatures being simultaneously taken at uniform car speed. In such a test, the voltmeter would reveal weak fields before they had commenced to cause vicious sparking, blowing of fuses and breakers, or to knock out armatures.

MOTOR HEATING TESTS

OBJECTS OF HEAT TESTS

221. Object of Factory Test. Factory heat tests are made to determine the temperature rise when a motor is run at full load a given time—usually 0.5 hour in each direction. A full heat test is seldom run in a repair shop, except for some special purpose—usually to test the effect of proposed changes.

222. Object of Shop Test. In car shops, heat tests may be made on repair armatures or to determine the effect of milling core slots or modifying the winding. Car-house men know that a motor with baked fields gets hot enough to give bearing troubles due to the lubricant thinning. In service, the field automatically regulates the motor current, so that if carbonization weakens the field, the motor takes excessive current and heats. In a shop test, however, the current is held at a predecided value and the only evidences of weak field would be increased speed and sparking. With the same current, a baked field heats less than a good one because its resistance is less and, therefore, cannot absorb as much energy. In a heat test, two motors are geared to an axle carried in suitable bearings. The frames remain in place and are adapted for readily installing and removing armatures that are to be tested.

223. *Note.* The rate at which heat energy is produced in a field is equal to the current multiplied by the drop across it. If the resistance of the field is less, the drop for given current will also be less; therefore, drop multiplied by current will be less and the field will not heat as much.

TEST CONNECTIONS

224. Self Excited Method. A dynamo is said to be *self excited* when it supplies its own field current. Fig. 66 gives connections for all circuit combinations required in a heat test in which both

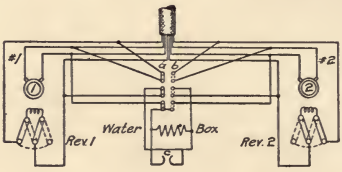


FIG. 66

machines in turn are run as motor and dynamo and in both directions. The field and armature wires are run to a controller that has the usual trolley and ground wires and resistance. Each machine has a separate reverse switch, for with given connections a self excited dynamo will generate in but one direction; as the dynamo must load the motor in both directions, extra switches save connecting and disconnecting. At *a* and *b* are single-throw, single-pole switches not required

to open an active circuit. When using machine No. 1 as motor, switches *a* are open and *b* closed; with No. 2 as motor, switches *b* are open and *a* closed. In Fig. 66, *a* and *b* are set for running No. 2 as motor and No. 1 as dynamo. The dynamo is always cut out in the controller. In series with the trolley, but not shown, is an ammeter for keeping the current constant. At *c* are two small hooks; a piece of small fuse wire laid across *c* short-circuits the water rheostat and enables the dynamo to generate promptly should the water give trouble.

225. Separately Excited Method. A dynamo is said to be *separately excited* when its field is magnetized by current due to an independent source; in the present case, the dynamo field is magnetized

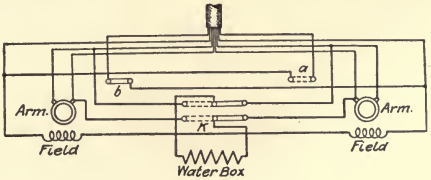


FIG. 67

by current from the motor circuit. A dynamo so excited will generate in either direction. The separate excitation method is ill adapted where temperature measurements are to be taken, because the drop in the dynamo field reduces the voltage applied to the motor, thereby decreasing its arma-

ture speed and certain losses depending on it. The requirements and connections are the same as those of the preceding test, except that the extra reverse switches are omitted, and are shown in Fig. 67. When machine No. 1 is used as motor, double-throw, double-pole switch K and single-throw, single-pole switch *b* are in the positions shown, switch *a* being in its dotted position or open. When No. 2 is the motor, K and *a* are closed and *b* opened. The fields of the two machines are connected in series as indicated.

TEST INSTRUCTIONS

226. Self Excited Method. Having installed two armatures, insert brushes and sandpaper them to fit the commutator. Put a handful of salt in the water box, shove the plates close together, see that no one is in a position to get hurt, then start the test; if the dynamo fails to generate, reverse its field; if it still fails to "pick up," lay a small wire across hooks *c*; with correct connections and no open-circuit, the machine will now generate, blowing the fuse at *c*. The strong residual magnetism due to the short-circuit current will enable the dynamo to generate through the water box. Having run at full load for half an hour, the test is shut down, the controller reverse switch thrown, the dynamo field reversed, the test started and run for another half hour at full load. If both armatures are to be tested, the test is again shut down, machine No. 2 cut out at the controller, No. 1 cut

in, switches *a* opened and *b* closed and the same tests run as in the first case.

227. *Note.* A single ground will not interfere with the operation of a circuit, but a second ground forms a by-path through which there can be a short-circuit current. Accordingly, in the preceding test, either the test rack must be grounded, or a point in the copper part of the motor circuit connected to the motor frame with a small fuse wire, which will blow, should a ground develop on the motor during the test.

228. Separately Excited Method. This test is run the same as the preceding except that there are no reverse switches.

TEST READINGS

229. Shop Test. In this test the current is kept at full load and the shaft speed taken at the beginning and end of test. When taking speed, the current should be right and the voltage as near right as practicable. The initial speed will exceed the final speed, owing to the greater drop in the heated windings. If the speed is stated at 500 volts and the voltage available is, say, but 450, the speed at 500 volts must be calculated: this can be done by the following rule:—

230. *Rule.* To calculate the speed at 500 volts from that at test voltage, Divide the standard voltage by the test voltage and multiply by the test speed.

231. *Example.* The speed of a shaft was 170

revolutions per minute at 450 volts. What would have been the speed in revolutions per minute at 500 volts?

232. *Solution.* $500 \div 450 = 1.11$ and $170 \times 1.11 = 188$ revolutions per minute.

233. *Note.* During the test the machine is watched for hot bearings, sparking, bent armature shaft, loose or eccentric commutator, open-circuit, short-circuit, endplay and grounds.

234. Temperature Test. If temperature rise is to be measured, voltage and current must be maintained at standard values. The temperature of the atmosphere is noted and the armature resistance measured. Noting the time, the test is started, full load put on and maintained constant for one hour. The test is then shut down, a thermometer placed on the armature and covered with waste. In the meanwhile the armature resistance is again measured. After about 25 minutes the thermometer is read.

235. Temperature Rise, calculated from the rise in resistance, is added to the room temperature at the time of starting, to get the final temperature of the armature.

236. *Rule.* To calculate the temperature rise of a copper winding from its rise in resistance, Subtract the resistance cold from the resistance hot, divide by the resistance cold and multiply by 258. The temperature rise added to the initial temperature, gives the final temperature in degrees centigrade.

237. *Example.* With a room temperature of 25 degrees centigrade (25° C.), the cold resistance of a motor field winding is 0.2 ohm and at the end of one hour's run at full load, the field resistance measures 0.26 ohm. Wanted (*a*) temperature rise and (*b*) final temperature of the winding.

238. *Solution.* (*a*) $0.26-0.20=0.06$; and $0.06 \div 0.20=0.3$; and (*b*) $0.3\times258=77.4$°C., temperature rise, Ans. $77.4+25=102.4$°C., Ans.

239. *Note.* The calculated final temperature will exceed that read on the thermometer, because the resistance method reaches the hottest part of the winding, while the thermometer does not.

240. Comparison of Thermometers can be effected as follows:—

241. *Rule.* To convert degrees centigrade into degrees fahrenheit, Multiply the °C. by 9, divide by 5 and add 32.

242. *Example.* In Ex. 12, express the final temperature as °F.

243. *Solution.* $9\times102.4=921.6$; and $921.6 \div 5=184.32$; $184.32+32=216.32$°F.

244. *Rule.* To convert degrees fahrenheit into degrees centigrade, Subtract 32 from °F., multiply by 5 and divide by 9.

245. *Example.* Express 216.32°F. as °C.

246. *Solution.* $216.32-32=184.32$; and $184.32\times5=921.6$; and $921.6 \div 9=102.4$°C.

EFFICIENCY TESTS

DEFINITIONS

247. Efficiency. The efficiency of a machine is the ratio of the power given out to the power put into it, both quantities being measured at the same time. The output is the numerator of a fraction of which the denominator is the input, both being expressed in the same units. The fraction is always less than 1, because no machine can put out all the work put into it:—hence the failure of all attempts at perpetual motion.

248. Commercial Efficiency of Motors. The commercial efficiency of a motor is the mechanical power available at the pinion, divided by the electrical power put into the motor. It is generally stated as the mechanical output divided by the electrical input, both being expressed in the same units.

249. Electrical Efficiency of Motors. The electric efficiency of a motor is a fraction, the numerator of which is the difference between the electrical input and electrical losses and the denominator of which is the electrical input. It is calculated.

250. Expression of Per Cent. Efficiency. Knowing the input and output of a machine, both expressed in the same unit, the percentage efficiency can be calculated by the following rule:—

251. *Rule.* To get the percentage efficiency of a machine from its output and input, Divide output by input and multiply by 100.

252. *Example.* The electrical input of a motor is 32,000 watts and its mechanical output 25,636 watts. Wanted its percentage efficiency.

253. *Solution.* $25{,}636 \div 32{,}000 = 0.8$; and $0.8 \times 100 = 80$ per cent.

ELECTRICAL EFFICIENCY TEST

254. Preliminaries. As the internal resistance, i.e., the combined field and armature resistances, of a hot motor exceeds that of a cold one, the hot losses will exceed the cold losses. As the efficiency sought is the efficiency under working conditions, a machine must run one hour at full load before measuring the resistances to be used in the efficiency calculations.

255. Calculations. Knowing the test current, voltage and internal resistance hot, the electric efficiency can be calculated as follows:—

256. *Rule.* To get the electric efficiency of a motor at stated current and voltage, the internal resistance hot being known, Multiply voltage and current to get watts input; next, multiply internal resistance and square of current to get watt losses. Finally, divide the difference between the input and loss by the input and multiply by 100. The result is per cent. electrical efficiency.

257. *Example.* The internal resistance hot of a 30 hp. railway motor is 0.3 ohm. Wanted,

electrical efficiency at full load on a 500-volt circuit.

258. *Solution.* 30 hp. $= 30 \times 746$ watts $=$ 22,380 watts $=$ input. 22,380 watts $\div 500$ volts $=$ 44.5 amperes $=$ full current load; $44.5 \times 44.5 =$ 1,980.25 $=$ square of current; $1{,}980 \times 0.3 = 594$ watts $=$ losses; $22{,}380 - 594 = 21{,}786$ $=$ difference; $21{,}786 \div 22{,}380 = 0.973$ $=$ electrical efficiency; $0.973 \times 100 = 97.3$ $=$ per cent. electrical efficiency.

COMMERCIAL EFFICIENCY TEST

259. Preliminary. To get commercial efficiency, the input must be measured electrically and the output mechanically. The electrical input can be measured with voltmeter and ammeter; the output is measured with a brake. As in the preceding case, the motor must be heated before taking measurements.

260. Mechanical Output. Fig. 68 shows a form of brake used to measure the output of a motor. M is an iron pulley; it is flanged on the outside to guide a steel strap, one end of which fastens to the lower end of clamp E and the other end to the upper end of E and also supporting a variable weight, W, on hanger D; M is flanged on the inside to hold water poured in after starting the test, to keep the pulley cool. The grip of the strap can be varied with the cord *t*. The armature turns from left to right and tends to drag W around but W resists this tendency. W and E are so adjusted that when the motor takes the current at which the

efficiency is to be tested, the hanger part of the strap is tangent to the pulley at radius O-T. The motor is bolted down and a guard may be put over the weights to prevent their giving trouble should the tester become confused. At full load current

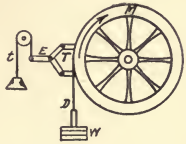


FIG. 68

and voltage, the armature speed is taken with an indicator. Knowing this speed in revolutions per minute, the radius of the pulley and weight W that balances the load, the output is calculated as follows:—

261. *Rule.* To get the watts absorbed by a brake on which weight W acts at the circumference perpendicular to the horizontal diameter, Multiply together the circumference of the pulley in feet, the revolutions per second, the weight of W in pounds and 1.36.

262. *Example.* A loaded armature makes 600 revolutions per minute, sustaining a weight W = 200 lb. at a radius of 18 in. Wanted, watts output.

263. *Solution.* $3 \times 3.1416 = 9.4248$ ft. = circumference of pulley; $600 \div 60 = 10$ revolutions per second; $1.36 \times 9.4248 \times 10 \times 200 = 25{,}636$ watts output.

264. *Note.* The object of multiplying by 1.36 is to reduce ft.-lb. per second to watts, there being 1.36 ft.-lb. per second to a watt.

265. Electrical Input. To measure the electrical input, connect an ammeter in series with the motor and a voltmeter across its terminals; the watts input is then calculated as follows:—

266. *Rule.* To get the watts input of a motor from its voltage and current, Multiply the voltage by the current.

267. *Example.* In the motor efficiency test of Ex. No. 263, the current is 64 amp. and the voltage 500 volts. Wanted, the motor input.

268. *Solution.* 500 volts $\times$ 64 amperes = 32,000 watts.

269. Final Calculations. As the commercial efficiency is the mechanical output $\div$ electrical input, the commercial efficiency is, in this case,

25,636 $\div$ 32,000 = 0.80; and 0.80 $\times$ 100 = 80 per cent. Ans.

ENERGY ABSORPTION TESTS

INTRODUCTORY

270. Energy absorption tests are made to determine directly the average power required to operate a car in service and indirectly other information used in comparing car performances.

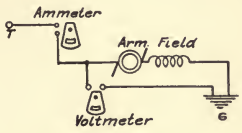


FIG. 69

Where cars are equipped with heat, light and compressor circuits, they must be opened if only the energy absorption of the motors is to be determined. The record must start and end with the trip and unusual delays must be noted.

WATT-HOUR METER METHOD

271. The easiest way to record an energy absorption test is with a watt-hour meter:—the meter field is connected in series with the motor circuit and the armature, across the line, as indicated in Fig. 70. The only readings to be taken are at the start and finish, except that allowance must be made for unusual delays. The difference between the start and finish readings, when multiplied by

the constant of the meter, gives the energy absorbed during the trip, expressed in watt-hours.

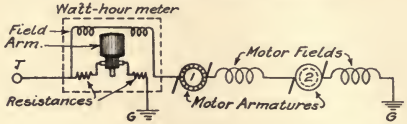


FIG. 70

272. *Note.* The *constant*, by which all readings are to be multiplied, is conspicuously displayed on the instrument.

273. *Note.* Unless the instrument is flexibly mounted for railway work, it should be spring-supported in the car.

INDICATING WATTMETER METHOD

274. The indicating wattmeter, a sketch of the connections of which is shown in Fig. 71, indicates the rate at which energy is being absorbed by the circuit at the instant of taking the reading. The large bare terminals connect in series with the

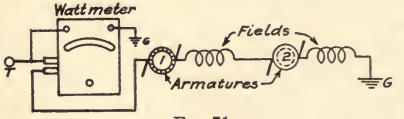


FIG. 71

motor circuit and the smaller, rubber covered terminals across the line. On pressing the button, the dead beat needle indicates the existing rate of energy absorption in the motor circuit. To get the

watt-hours of energy absorbed in a given time, numerous equi-spaced readings taken during that time must be averaged and the average multiplied by the time in hours. The readings are started and ended with the trip and the closer together they are, the more correct the results. A satisfactory way to get numerous equi-spaced readings is to take them deliberately, and, as soon as one is taken, take another in the same manner.

275. *Rule.* To get the watt-hours absorbed in a given time from the readings of an indicating wattmeter, Add the readings and divide by their number to get the average reading expressed in watts; then multiply by the time in hours.

276. *Example.* In 130 seconds, the following indicating wattmeter readings were taken. Wanted, the watt-hours absorbed.

277. *Solution.* 80,080 + 0 + 0 + 63,750 + 120,750 + 0 + 85,800 + 27,000 + 85,000 + 82,500 + 0 + 96,800 + 0 + 0 + 0 + 112,000 + 86,350 + 0 + 37,800 + 0 + 86,840 + 81,120 + 86,350 + 84,530 + 86,940 + 84,530 = 1,388,140 = sum of the readings; 1,388,140 ÷ 26 = 53,390 = average watts; and 53,390 × .036 = 1,922 -.04 watt-hours absorbed during the test.

278. *Note.* 130 seconds is 2 min. and 10 sec. or $2\frac{1}{6}$ minutes; the time in hours is, then, $2\frac{1}{6} \div 60 =$ 0.036 hour.

VOLTMETER–AMMETER METHOD

279. In this test the ammeter is connected in series with the motor circuit and the voltmeter

across the line. Simultaneous readings are taken on both and put down opposite each other, as indicated in the following sample test sheet, where volts are in the first column, amperes in the second, and their product, watts, in the third. As the meter readings must be taken simultaneously, they are best taken by two operators one of whom gives the signal. If, as soon as one set of readings is taken and put down, another is taken and recorded in the same manner, they will be frequent and equispaced—two desirable conditions. Unless accustomed to take sight readings, the operator will be tempted to wait until a moving needle stops, before taking a reading; this temptation must be overcome or the results may be in error. The instruments should be supported in boxes filled with waste and before starting, the tester should be certain that the capacity of the ammeter is sufficient for all currents likely to be measured. To look after possible short-circuits, the ammeter should be provided with a short-circuiting switch, with which to cut the meter out should any warning of short-circuit be given. As the resistance of an ammeter is low, the instrument will register some current even when the short-circuiting switch is closed, so care must be had to take no readings with the ammeter short-circuited, as the test would then have to be repeated. After all readings have been taken and recorded, each voltmeter reading is to be multiplied by its corresponding ammeter reading and the product, watts, put opposite in

the column marked W. This product is the watts or rate at which energy was being absorbed by the motor circuit at the instant of taking the simultaneous voltmeter and ammeter readings and represents the reading that an indicating wattmeter would have given.

ABSORPTION TEST, RECORD SHEETS

280. Sample record sheet of an actual voltmeter-ammeter test:—

Volts	Amp.	Watts	Volts	Amp.	Watts
450	0	0	560	0	0
410	0	0	575	0	0
475	110	52,250	570	0	0
410	85	34,850	.....	....	.....
390	215	83,850	570	83	47,310
460	85	39,100	535	74	39,590
420	0	0	575	0	0
460	0	0	510	213	108,630

281. From data gotten before the test and from the test readings, the following information becomes available:—

Car number	1,526
Car weight (lbs.)	42,380
Number motors per car	4
Rated hp. per motor	40
Rated hp. of equipment	160
Full load current (amp.)	239
Type of controller	K-6
Condition of rail	Good
Time of start (p.m.)	2.3
Time of stop (p.m.)	4.4
Total duration (min.)	121

Delays (min.)	18
Actual duration (min.)	103
Actual duration (hr.)	1.72
Distance (miles)	17.78
Route	Bergen Turnpike
Number voltmeter readings	509
Sum of voltmeter readings	262,095
Average voltmeter readings	514
Maximum voltmeter readings	625
Minimum voltmeter readings	360
Number ammeter readings	509
Number current readings	281
Sum current readings	43,773
Average current—all readings	86
Average current—current readings	156
Maximum current readings	355
Maximum power readings (watts)	191,700
Number power readings	281
Sum power readings	21,851,395
Average power—all readings (watts)	42,930
Average power—current readings	77,763
Average speed (miles per hr.)	10.36
Total energy absorbed (watt-hours)	73,667.88
Kilowatts (Average)	42.93
Kilowatt-hours per mile	4.14
Kilowatt-hours per ton	3.47
Kilowatt-hours per ton-mile	0.195
Kilowatts per ton	2.02
Maximum hp. exerted	254.20
Average hp. exerted	57.50
Total energy absorbed (horsepower hours)	104
Date of test	April 10th, 1906
Chief observer	Edward Ford

ANALYSIS OF TEST SHEET

282. Weight of Car (Equipped). The car weight is gotten by actual weighing; if the scale

is too small to weigh the whole car, weigh one end at a time and add the weights.

283. *Rule.* Given a car weight in pounds, to get its weight in tons, Divide the pounds weight by 2,000.

284. *Example.* A car weighs 42,380 lb. Wanted, the weight in tons.

285. *Solution.* $42{,}380 \div 2{,}000 = 21.19$ tons.

286. *Note.* If the weight is given in tons, and the weight in pounds is desired, Multiply the weight in tons by 2,000.

287. Rated Horsepower of Equipment. The rated horsepower of equipment can be gotten from the number of motors and horsepower per motor, as follows:—

288. *Rule.* To get rated horsepower of equipment from number of motors and horsepower per motor, Multiply the number of motors by the horsepower per motor.

289. *Example.* A four-motor car has 40 horsepower motors. What is the rated horsepower of the equipment?

290. *Solution.* 4×40 hp. $= 160$ hp.

291. Rated Full Load Current. This can be gotten as follows:—

292. *Rule.* To get the rated full load current of equipment, Multiply horsepower of equipment by 746 and divide by rated voltage.

293. *Example.* A four-motor car has 40 hp. motors. What is the rated full current load of the equipment on a 500-volt service?

294. *Solution.* $4 \times 40 = 160$ hp.; and $160 \times 746 = 119{,}360$ watts; and $119{,}360 \div 500 = 239$ amp.

295. *Note.* Should the motors be rated at some other voltage than 500 volts, Divide by that rated voltage instead of 500.

296. Duration of Test (min.). The duration of test is the actual time required to make the trip less unusual delays during which readings were not taken. In the present case, the total duration (121 min.) less delays en route and at terminals (18 min.), leaves 103 min. as the duration of the test.

297. Duration of Test (hr.). As the hour is the unit used in calculations, the time in min. is reduced to hr., as follows:—

298. *Rule.* To reduce the duration in minutes to duration in hours, Divide by 60.

299. *Example.* The duration of the test is 103 min. Wanted, the duration in hours.

300. *Solution.* $103 \div 60 = 1.72$ hrs.

301. Distance Covered. The distance covered can be gotten from the operating department where it is used in making up time tables; if not available, it can be derived as follows:—

302. *Directions.* Start two men from opposite ends of the route, to count the rails in one side of one track; the number of rails $\times 2$ gives the number of end on rails in the round trip.

303. *Rule.* To get the distance in miles from the number of end on rails in one rail line, Multiply

the feet per rail by the number of rails and divide by 5,280.

304. *Example.* A test route includes 3,129.25, 30 ft. rails in one rail line. What is the distance in miles?

305. *Solution.* $3{,}129.25 \times 30 = 93{,}877.5$ ft.; and $93{,}877.5 \div 5{,}280 = 17.78$ miles.

306. *Note.* Rail pieces used at crossings must be reduced to lengths. If two lengths of rails are used, note the number of each.

307. Number of Voltmeter Readings. As the voltmeter is read whether there is current or not, the number of voltmeter readings is the total number of readings—in this case, 509, and their sum is 262,095.

308. Average Voltage. The average voltage is calculated from the number of voltmeter readings and their sum, as follows:—

309. *Rule.* To get average voltage from the sum of a given number of readings, Divide the sum by the number.

310. *Example.* The number of voltmeter readings being 509 and their sum 262,095, what was the average voltage during the test?

311. *Solution.* $262{,}095 \div 509 = 514$ volts.

312. Maximum and Minimum Voltages. The maximum voltage is the highest voltmeter reading recorded; the minimum, the lowest, unless otherwise stated.

313. *Note.* In throwing out a maximum reading that is questionable, the next highest is

taken as maximum. In throwing out a minimum reading, the next lowest is taken as minimum. Where a reading is thrown out it must be ignored entirely.

314. Ammeter and Current Readings. 509. The ammeter readings include the 0 current readings; the 281 current readings do not. The sum of the readings is the same in both cases—43,773.

315. Average Current-all Readings. The average current of all readings can be determined from the following rule:—

316. *Rule.* To get the average current of all readings, Divide the sum of the ammeter readings by their number.

317. *Example.* The sum of the ammeter readings is 43,773 and their number 509. Wanted, the average current of all readings.

318. *Solution.* $43{,}773 \div 509 = 86$ amp.

319. Average Current-current Readings. The average current of the current readings can be gotten from the following rule:—

320. *Rule.* To get the average current of the current readings, Divide the sum of the current readings by the number of current readings.

321. *Example.* The sum of 281 current readings being 43,773, What is the average current of the current readings?

322. *Solution.* $43{,}773 \div 281 = 156$ amp.

323. *Note.* The sum of the ammeter and current readings is the same, because adding zeros does not increase the sum.

324. Maximum Current. The maximum current is the largest ammeter reading recorded; in the present case it was 355 amperes.

325. *Note.* If a greater current is known to have occurred than appears on the test record, it can be noted as a matter of information but must not be used in calculations.

326. *Note.* Should a flash-over or other abnormal condition cause excessive current while taking a reading, Put down a current value consistent with preceding and following values.

327. Maximum Power Reading. The maximum power reading is the largest product in the watts column of the test record—in the present case, 191,700 watts. When the current reading is 0, the power reading is also 0, because the power reading is the product of the volt and ampere readings and if the amperes are 0 the product must be.

328. *Note.* In the present test, the maximum power and current readings corresponded, but this is but a coincidence, as the voltage corresponding to a lesser current might easily have been sufficiently greater to make the product exceed 191,700.

329. Total and Actual Power Readings. The total number of power readings, 509, include the zeros; the actual power readings, 281, do not. The former are used in calculating the average power of all readings; the latter, the average power of current readings.

330. Average Power-all Readings. This can be calculated as follows:—

331. *Rule.* To get the average power of all readings, Divide the sum of the power readings by the total number.

332. *Example.* The sum of 509 power readings is 21,851,395. Wanted, the average power of all power readings.

333. *Solution.* $21,851,395 \div 509 = 42,930$ watts.

334. Average Power-current Readings. The average power of the current readings may be calculated from the following rule:—

335. *Rule.* To get the average power during the actual power readings, Divide the sum of the actual readings by their number.

336. *Example.* The sum of 281 actual power readings is 21,851,395. Wanted, average power of actual power readings.

337. *Solution.* $21,851,395 \div 281 = 77,763$ watts.

338. Average Speed. The average speed during the test can be determined from the distance in miles and the time in hours.

339. *Rule.* To get the average car speed, Divide the distance in miles by the time in hours required to traverse it.

340. *Example.* The distance traveled in a test is 17.78 miles and the time, 1.716 hours. Wanted the average speed in miles per hour.

341. *Solution.* $17.78 \div 1.716 = 10.36$ miles per hour.

342. *Note.* The average speed seems low, but it includes the time consumed by frequent stops—a very considerable item.

343. Total Energy Absorbed (watt-hours). The total energy absorbed is the average rate of absorption (watts) $\times$ the time (hours) during which it acted and is, therefore, expressed in *watt-hours*.

344. *Rule.* To get the watt-hours absorbed, Multiply the time in hours by the average power in watts during the test.

345. *Example.* The average power is 42,930 watts and the duration, 1.716 hours. Wanted, watt-hours of energy absorbed.

346. *Solution.* $42{,}930 \times 1.716 = 73{,}668$ watt-hours.

347. Total Energy Absorbed (kw.-hr.). To avoid large numbers, the energy unit generally employed is the *kilowatt-hour* (kw.-hr.) which is 1,000 watt-hours. It is gotten from the watt-hours as follows:—

348. *Rule.* To convert watt-hours into kilowatt-hours, Divide by 1,000.

349. *Example.* Convert 73,668 watt-hours into kilowatt-hours.

350. *Solution.* 73,668 watt-hours $\div$ 1,000 = 73.668 kilowatt-hours.

351. *Note.* To convert kilowatt-hours into watt-hours, Multiply by 1,000.

352. Total Energy Absorbed (horsepower-hours). Kilowatt-hours are converted into horsepower-hours (hp.-hr.), by applying the following rule:—

353. *Rule.* To convert kilowatt-hours into horsepower-hours, Multiply by 1.34.

354. *Example.* Convert 77.668 kw.-hr. into horsepower-hours.

355. *Solution.* 77.668 kw.-hr. $\times 1.34 = 104$ hp.-hr.

356. *Note.* To convert horsepower-hours into kilowatt-hours, Divide by 1.34.

357. *Example.* Convert 104 hp.-hr. into kilowatt hours.

358. *Solution.* 104 hp.-hr. $\div 1.34 = 77.668$ kw.-hr.

359. Average Kilowatts. To compare the power required by different equipments over the same or different routes, it may be desirable to know the average kilowatts, so that comparisons may be independent of the durations of the several tests. In railroad work, in such cases, kilowatts are generally called kilowatt-hours per hour, both units being mathematically the same.

360. *Rule.* To get the average kilowatts or kilowatt-hours per hour of an absorption test, Divide the total kilowatt-hours by the time in hours.

361. *Example.* The total kilowatt-hours of a test are 73.66 and duration, 1.716 hr. Wanted, average kilowatts or kilowatt-hours per hour of the test.

362. *Solution.* $73.66 \div 1.716 = 42.93$ kw. or kw.-hr. per hr.

363. Kilowatt-hours per Mile. The kilowatt-hours per mile are obtained as follows:—

364. *Rule.* To get the kilowatt-hours per mile of an absorption test, Divide the total kilowatt-hours by the distance covered in miles.

365. *Example.* The total kilowatt-hours ab-

sorbed is 73.66 and the distance covered, 17.78 miles. Wanted, the kilowatt-hours per mile.

366. *Solution.* $73.66 \div 17.78 = 4.14$ kw.-hr. per mile.

367. Kilowatt-hours per Ton. To get the kilowatt-hours per ton, in an absorption test, apply the following rule:—

368. *Rule.* To get the kilowatt-hours per ton, in an absorption test, Divide the total kilowatt-hours by the weight of the car in tons.

369. *Example.* The weight of a car is 21.19 tons and the total kilowatt-hours, 73.66. What is the absorption in kilowatt-hours per ton?

370. *Solution.* $73.66 \div 21.19 = 3.47$ kw.-hr. per ton.

371. Kilowatts per Ton. Kilowatt-hours per ton is not a good unit for comparing tests, unless they have the same duration. A better basis is the kilowatts per ton (or kilowatt-hours per hour per ton).

372. *Rule.* To get the average kilowatts per ton (or kilowatt-hours per hour per ton), Divide the total kilowatt-hours of the test by the product of the duration in hours and the car weight in tons.

373. *Example.* The total kilowatt-hours is 73.66, the duration, 1.716 hours and the car weight, 21.19 tons. Wanted, the kilowatts per ton.

374. *Solution.* $21.19 \times 1.716 = 36.36$; and $73.66 \div 36.36 = 2.02$ kw. per ton (or kw.-hr. per hour per ton).

375. Kw.-Hr. per Ton-mile. The kilowatt-hours of energy absorbed per mile by each ton of car weight can be calculated as follows:—

376. *Rule.* To get the average kilowatt-hours per ton-mile, Divide the total kilowatt-hours by the tons car weight $\times$ the miles traveled.

377. *Example.* The total kilowatt-hours are 73.66; the distance, 17.78 miles; the weight, 21.19 tons. Wanted, the kilowatt-hours per ton-mile.

378. *Solution.* $21.19 \times 17.78 = 376.75$; and $73.66 \div 376.75 = 0.195$ kw.-hr. per ton-mile.

379. Concluding Remarks. The absorption test is more instructive if the per cent. of all grades along the route is determined and the grades named so that they can be noted as they are reached; the watts column will then show at once the rate of absorption due to different per cent. grades.

380. The average voltage of the test is 514 volts; the average current, 86 amperes; the product of these average values is 44,204 watts, which is fairly close to the correct result of multiplying together corresponding voltmeter and ammeter readings and averaging the products; and there is temptation to use the shorter but meaningless method of obtaining a result just as liable to be too small as too great.

381. The voltmeter-ammeter test is laborious, but gives more information on voltage, current and incidents than a wattmeter test. But few roads have a wattmeter sufficiently large to measure the energy

absorbed by a heavy, four-motor car. Most of them, however, have voltmeters and ammeters the capacities of which can be sufficiently increased by multipliers and shunts.

MISCELLANEOUS TESTS

SPEED TESTS

382. Rail-count Method. An approximate speed test depends on a relation between the number of rails traversed per second and the car speed in miles per hour. The relation is as follows:—

383. *Rule.* The number of 30-ft. rails traversed by a car in 20 sec. is the speed of the car in miles per hour.

384. *Example.* A car jounces over 61 joints in 60 sec. on a track laid with 30 ft. rails. Wanted, the car speed in miles per hour.

385. *Solution.* As 1 joint is passed before a rail has been traversed, 61 joints in 60 sec. is 60 rails in 60 sec. or one rail per sec. i. e., 20 rails in 20 sec. or a speed of 20 miles per hour.

386. *Rule.* If the rails are 60 ft. long, the car speed in miles per hour is twice the number of rails traversed in 20 sec. or number of rails passed in 40 sec.

387. *Example.* A car jounces over 61 joints in 60 sec. on a track laid with 60-ft. rails. Wanted, the car speed in miles per hour.

388. *Solution.* 61 joints per min. is 60 rails per min. or 1 per sec. i. e., 20 rails in 20 sec.; $2 \times 20 = 40$ miles per hour.

389. *Note.* Only the joints on one side are to be counted.

390. Pole-count Method. Knowing the distance apart of the line poles and the number of pole spaces passed in 1 minute, the car speed in miles per hour can be determined as follows:—

391. *Rule.* To get car speed in miles per hour from the distance apart of the line poles and the number of poles passed per minute, Subtract 1 from the number of poles per minute to get the number of spaces per minute. Then multiply together the number of spaces, the length of a space in feet and 0.0113.

392. *Example.* The line poles average 112 ft. apart and a car passes 14.5 poles per min. Wanted, the car speed in miles per hour.

393. *Solution.* $14.5-1=13.5$; and $13.5\times112\times0.0113=17$ miles per hour.

394. Minutes per Half-hour Method. To find the maximum speed attainable on level track at standard voltage, lay off a half mile, mark it plainly and, with a stopwatch, take the time required by the car to traverse the distance between the marks, the car approaching the first mark at full speed; this done, the speed of the car in miles per hour can be calculated by the following rule:—

395. *Rule.* To get car speed in miles per hour from the time (min.) required to run one-half mile, Divide 30 by the time in minutes.

396. *Example.* A car traverses a laid off half mile in 1.5 minutes. What is its speed in miles per hour?

397. *Solution.* $30\div1\frac{1}{2}=20$ miles per hr.

398. *Note.* Motors are often bought under guarantee to run a car of given weight a stated speed at standard voltage. This test should be made after the car has been limbered up by several days of operation. If the speed then is low, See that the voltage is standard and that the controller operates to cut out all resistance on the last parallel position.

ACCELERATION TESTS

399. Miles per Hour per Second. (Miles per hr. per sec.). By acceleration is meant change of speed per unit of time, irrespective of whether the change is an increase or a decrease. Usage, however, accepts acceleration to mean *increase* in speed per unit of time, the unit of time generally used being the second. If a car acquires a speed of 15 miles per hr. from rest, the gain in speed is 15 miles per hr.; but before the acceleration or the *rate of change of speed* can be expressed, the time in seconds required to make the gain must be known. If 12 sec. elapse between rest and a speed of 15 miles per hour, the average speed increase per second, or acceleration, is $\frac{1}{12}$ the total increase or 1.25 miles per hr. per sec.

400. *Rule.* To find in miles per hr. per sec. the acceleration from rest to given speed acquired in given time, Divide the miles per hour speed by the time in seconds required to attain the speed.

401. *Example.* A car acquires a speed of 16 miles per hour in 13 sec. What is its acceleration in miles per hr. per second?

402. *Solution.* 16 miles per hr. ÷ 13 sec. = 1.23 miles per hr. per sec.

403. Feet per Second per Second. Miles per hr. per sec. can be converted into ft. per sec. per sec. by the following rule:—

404. *Rule.* To convert miles per hr. per sec. into ft. per sec. per sec., Multiply the miles per hr. per sec. by 1.47.

405. *Example.* Convert 1.25 miles per hr. per sec. into ft. per sec. per sec.

406. *Solution.* 1.25 miles per hr. per sec. × 1.47 = 1.83 ft. per sec. per sec.

407. *Note.* To convert acceleration in ft. per sec. per sec. into acceleration in miles per hr. per sec., Divide the ft. per sec. per sec. by 1.47.

408. Time of Acceleration. The time of acceleration can be obtained as follows:—

409. *Directions.* To get the time of accelerating a car from rest to given speed, Connect an ammeter in series with the motor circuit, start the car and a stopwatch simultaneously and stop the watch the instant the steady ammeter needle shows the speed to be uniform:—the time elapsed on the watch will be the time of acceleration in seconds.

410. *Note.* The time test should be repeated under the same conditions until several tests check well in point of time.

411. Distance of Acceleration. This means the rail distance covered by the car during acceleration; it is best obtained by measuring with a tape line

the distance between the initial and final positions of the car during its acceleration.

412. Average Speed of Acceleration. By timing the acceleration and measuring the distance covered during that period, the average speed can be determined from the following rule:—

413. *Rule.* To get the average speed during acceleration in ft. per sec., Divide the distance of acceleration in feet by the time in seconds. Or multiply the acceleration by the time in sec. and divide by two.

414. *Example.* In accelerating from rest, a car travels 152 ft. in 13 sec. What is the average speed in feet per second?

415. *Solution.* 152 ft. ÷ 13 sec. = 11.69 ft. per sec. Or $1.80 \times 13 \div 2 = 11.7$.

416. *Note.* To convert ft. per sec. into miles per hr., Divide by 1.47. To convert miles per hr. into ft. per sec., Multiply by 1.47.

417. *Example.* An average speed of 11.69 ft. per sec. = how many miles per hr.?

418. *Solution.* 11.69 ft. per sec. ÷ 1.47 = 7.95 miles per hr.

419. *Example.* Convert 7.95 miles per hr. into speed in ft. per sec.

420. *Solution.* 7.95 miles per hr. × 1.47 = 11.69 ft. per sec.

421. Maximum Speed of Acceleration. This can be gotten as follows:—

422. *Rule.* To get the maximum speed due to acceleration of a car started from rest, Multiply the average speed of acceleration by two. The maximum speed will be in the same units as average speed.

423. *Example.* The average speed of a car during acceleration is 11.69 ft. per sec. or 7.95 miles per hr. Wanted, (a) maximum speed in ft. per sec. and (b) in miles per hour.

424. *Solution.* (a) 11.69 ft. per sec. $\times 2 = 23.38$ ft. per sec. and (b) 7.95 miles per hour $\times 2 = 15.9$ miles per hour.

425. *Proof.* From Note of Art. 416, 15.9 miles per hr. $\times 1.47 = 23.38$ ft. per sec.

426. *Note.* To get the average speed of acceleration from the maximum speed of acceleration, Divide the maximum speed by two.

427. Force of Acceleration. This means the force in pounds to be applied as a push or pull in the direction of motion, to produce a given acceleration in miles per hr. per sec. or ft. per sec. per sec.

428. *Rule.* To get the force in pounds required to accelerate a car of given weight in tons at a given rate in miles per hr. per sec., Multiply the product of the weight and acceleration by 91.2.

429. *Example.* A 10-ton car is to be given an acceleration of 1.23 miles per hr. per sec. What force will be required?

430. *Solution.* $10 \times 1.23 \times 91.2 = 1{,}122$ lb.

431. Where the acceleration is given in ft. per

sec. per sec., the force of acceleration can be gotten from the following rule:—

432. *Rule.* To get the force in pounds required to produce a given acceleration in ft. per sec. per sec. of a car of given weight in tons, Multiply together the weight, acceleration and 62.32.

433. *Example.* A 10-ton car is to be accelerated 1.8 ft. per sec. per sec. Wanted, the force required to produce this acceleration.

434. *Solution.* $10 \times 1.8 \times 62.32 = 1{,}122$ lb.

435. Horsepower of Acceleration. This means the horsepower required to accelerate a car to given speed, independently of the horsepower expended in overcoming frictional resistances, to be considered later.

436. *Rule.* To get the horsepower of acceleration, Multiply the force of acceleration (lb.) by the distance (ft.) and divide by $550 \times$the time in seconds.

437. *Example.* A force of 1,122 lb. accelerates a car to full speed in 13 sec. over a distance of 152 ft. At what hp. i. e., rate, was energy expended in accelerating the car?

438. *Solution.* $1{,}122 \times 152 = 170{,}544$; and $550 \times 13 = 7{,}150$; and $170{,}544 \div 7{,}150 = 23.8$ hp.

439. *Note.* As electric cars are not accelerated at a uniform rate, owing to resistances being cut out in impulses, the force acting during acceleration is not constant; the calculated force is, then, the

average force of acceleration and the calculated hp. the average hp. during acceleration.

RETARDATION TESTS

440. Introductory Remarks. Retardation means rate of decrease in speed and is here understood to be due to the car brake. With an air-brake in good order, it is comparatively easy to measure the time elapsing between the application of the brake and the stopping of the car, because air-brakes act promptly on operating the motorman's valve to admit air to the brake cylinder. On a hand-braked car, however, the time elapsing depends more on the condition and effectiveness of the rigging and the effort of the brakeman, so that reliable results are to be gotten only by having lost motion and clearance a minimum and by repeating tests until results check. An air-brake applies maximum braking force initially when the car speed is greatest and the liability to lock wheels least; a hand-brake applies the braking force at a gradually increasing rate, owing to the time required to bring it into action.

441. Miles per Hour per Second. The retardation in miles per hr. per sec. can be determined as follows:—

442. *Directions.* To determine the retardation of a car in miles per hr. per sec., Bring the car to uniform speed, as indicated by an ammeter in the motor circuit, on level track; at a given signal, start a stop-watch and apply the brake; the instant

the car stops, stop the watch and note the position of the car. Repeat the test several times under the same conditions, each time carefully noting the initial and final positions of the car, so that the distance of retardation can be measured. Having the distance in miles and the time in seconds, the retardation in miles per hr. per sec. can be determined as follows:—

443. *Rule.* To get retardation in miles per hr. per sec. from maximum speed in miles per hr. and time, in seconds, Divide the speed by the time.

444. *Example.* A car running at 16 miles per hr. is brought to a stop in 11 sec. Wanted, the retardation in miles per hr. per sec.

445. *Solution.* 16 miles per hr. $\div$ 11 sec. $=$ 1.45 miles per hr. per sec.

446. Feet per Second per Second. Miles per hr. per sec. can be converted into ft. per sec. per sec. by applying the following rule:—

447. *Rule.* To convert retardation in miles per hr. per sec. into retardation in ft. per sec. per sec., Multiply by 1.47.

448. *Example.* The retardation of a car is 1.45 miles per hr. per sec. Express this retardation as ft. per sec. per sec.

449. *Solution.* $1.45 \times 1.47 = 2.13$ ft. per sec. per sec.

450. *Note.* As in the case of acceleration to convert ft. per sec. per sec. into miles per hr. per sec., Divide by 1.47.

451. Distance of Retardation. This means the length of rail covered during retardation and is best gotten by actual measurement, with a tape line, between the positions of the car, when starting the stop-watch and stopping it.

452. Average Speed During Retardation. This can be gotten from time and distance of retardation by substituting retardation for acceleration in the rule of Art. 413 or divide the speed of the car by two.

453. *Example.* A car is brought from maximum speed to rest in 11 sec., traversing 128.7 ft. Wanted average speed during retardation.

454. *Solution.* $128.7 \div 11 = 11.7$; and $11.7 \times 1.47 = 8$ miles per hr. or $16 \div 2 = 8$.

455. Maximum Speed During Retardation. This is the speed existing at the time of applying the brake in the retardation test and can be gotten by applying the rule of Art. 422.

456. *Example.* The average speed during retardation being 8 miles per hr., wanted the maximum speed during retardation in miles per hr.

457. *Solution.* 8 miles per hr. $\times 2 = 16$ miles per hr., maximum speed.

458. Concluding Remarks. Under similar conditions a car can be retarded from given speed to rest in less time and distance than it can be accelerated from rest to that same speed, because (a) all frictional forces help retardation but oppose acceleration; (b) where controllers have but few notches, accelerating force cannot be applied to as good

advantage as can the retarding force due to a good brake.

459. Acceleration tests may be run to determine the smoothness of controller notching for the purpose of improving it so as to get quick, smooth starting, to save time. In service that has frequent stops, the time lost in poor acceleration is considerable, and the motormen's efforts to compensate for it by rapid notching, invite accidents. The same can be said of retardation as related to badly designed or poorly maintained brakes. In addition, retardation tests may be run to determine the relative effectiveness of different makes or types of shoes or riggings; or such tests may be made on particular cars that have been involved in an accident, to determine the minimum distance in which the car might have been stopped.

TRAIN RESISTANCE

460. Introductory Remarks. Train resistance is the opposition of various forms of friction to train motion. If a car is raised to speed, the power turned off and the car permitted to roll along or *coast*, train resistance will, in time, stop the car unless it is on the down grade; on an up grade, the car will stop sooner, but then the stop is due to combined grade and train resistance. Except for grades, train resistance is the only retarding agent to be overcome by the motors, and were it not for train resistance, a car once started on level track would run on at undiminished speed

without any further application of motive power.

461. Measurement on Level Track. This measurement requires about 1,000 ft. of straight, level track; it is made as follows:—

462. *Directions.* To measure train resistance on level track, Accelerate the car to full speed, as indicated by an ammeter; at a given signal, throw off the power, start the watch, note the position of the car, allow it to coast to rest, stop the watch and again note the position of the car. Knowing the distance (ft.) and time (sec.) of coasting, the average speed is determined from the rule of Art. 413 and the maximum speed from the rule of Art. 422.

463. Knowing the maximum speed in ft. per sec., the distance in feet and the car-weight in pounds, the train resistance is gotten as follows:—

464. *Rule.* To calculate total train resistance from maximum speed, distance traversed in coasting and car-weight, Divide the car-weight in pounds by 32 and multiply by the square of the speed in ft. per sec.; then divide by twice the distance in feet. The result will be the total train resistance in pounds.

465. *Example.* Train resistance alone brings a 20-ton car from full speed to rest in 58.6 sec., the coasting distance traversed being 688 ft. Wanted, the total train resistance.

466. *Solution.* $40{,}000 \div 32 = 1{,}250$; from the rule of Art. 413, 688 ft. $\div$ 58.6 sec. $= 11.728$ ft. per sec., average speed; from the rule of Art. 422,

$11.728 \times 2 = 23.456$ ft. per sec., maximum speed; $23.456 \times 23.456 = 550.18$, square of speed; $550.18 \times 1{,}250 = 687{,}725$; 2×688 ft. $= 1{,}376$ ft., twice the distance; $687{,}725 \div 1{,}376 = 500$ lb., total train resistance.

467. *Note.* The term train resistance generally refers to the resistance per ton. To get the train resistance per ton from the total train resistance and the car weight in tons, Divide the total train resistance by the number of tons. The train resistance per ton in the last example is 500 lb. $\div 20 = 25$ lb.

468. Measurement on Grades. On a grade, the difference in level between the points where coasting starts and the car stops must be known, so that the retarding effect of the grade can be calculated and deducted. Knowing the distance in which train resistance and the grade stop the car and the distance through which the car is raised by the grade, the retarding effect of the grade can be calculated as follows:—

469. *Rule.* To get the retarding resistance of a grade on a car of given weight in pounds, Multiply the car-weight in pounds by the distance raised in feet, and divide by the coasting distance in feet. The result will be the grade resistance in pounds.

470. *Example.* Combined train and grade resistances bring a 40,000-lb. car from 16 miles per hr. to rest in 344 ft., the rise being 4.3 ft. Wanted, the train and grade resistance per ton.

471. *Solution.* From the rule of Art. 464,

$40{,}000 \div 32 = 1{,}250$; $23.456 \times 23.456 = 550.18$; $550.18 \times 1{,}250 = 687{,}725$; $687{,}725 \div 688 = 1{,}000$ lb., combined train and grade resistances; from the rule of Art. 469, $40{,}000 \times 4.3 = 172{,}000$; $172{,}000 \div 344 = 500$ lb., total resistance of grade; 1,000 lb. $-$ 500 lb. $=$ 500 lb., total train resistance; 500 lb. $\div 20 = 25$ lb., train resistance per ton; 500 lb. $\div 20 = 25$ lb., grade resistance per ton.

472. *Note.* The apparent train resistance is calculated as if no grade existed (Rule of Art. 464). The grade resistance is then calculated by the rule of Art 469 and subtracted from the apparent train resistance, to get the total train resistance.

HORSEPOWER OF TRACTION

473. Introductory Remarks. Horsepower of traction here means average rate at which energy must be absorbed to carry a car of given weight a given distance in a given time. Two cases will be be considered:—

1. On level track where only train resistance opposes movement.
2. On grades where grade resistance has retarding effect.

474. Ft. per Sec. Method on Levels. Given train resistance in pounds per ton, car speed in ft. per sec. and car-weight in pounds, calculate horsepower as follows:—

475. *Rule.* To get the average horsepower of traction of a car of given weight, at given speed, against given train resistance per ton, Multiply

together weight of car in tons, speed and train resistance per ton and divide by 550.

476. *Example.* A 20-ton car runs 16 miles per hr. on a level against a train resistance of 25 lb. per ton. Wanted, the average horsepower absorbed.

477. *Solution.* From the note of Art. 416, 16 miles per hr. $\times 1.47 = 23.5$ ft. per sec. From the rule of Article 475, 20×25 lb. $= 500$ lb.; $500 \times 23.5 = 11{,}750$ ft.-lb. per sec.; and $11{,}750 \div 550 = 21.3$, average horsepower absorption.

478. Miles per Hr. Method on Levels. Given car weight in tons, speed in miles per hr. and train resistance in pounds per ton, the average horsepower of traction can be calculated from the following rule:—

479. *Rule.* To get the average horsepower of traction of a car of given weight, at given speed, against given train resistance (lb. per ton) on a level, Multiply the car-weight in tons, speed and train resistance and divide by 375.

480. *Example.* What is the average horsepower required to run a 20-ton car at 16 miles per hr. against a train resistance of 25 lb. per ton?

481. *Solution.* $16 \times 20 \times 25 = 8{,}000$; $8{,}000 \div 375 = 21.3$ horsepower.

482. Calculation of Grade Effect. To find the horsepower required to take a car of given weight up a given grade, at given uniform speed, the train resistance per ton being known, the horsepower of train resistance is calculated by the rule of Art. 475 and to it is added the horsepower required to

overcome the grade. To calculate the horsepower necessary to overcome the grade, the *net rise* or rise per ft. of track must be known.

483. *Rule.* To get the horsepower required to run a car of given weight (lb.), at given uniform speed (ft. per sec.) up a grade of given rise per foot, Multiply the car-weight, the rise per foot and the speed together, then divide by 550.

484. *Example.* Wanted, the horsepower required to impel a 20-ton car up a grade that rises 0.0125 ft. in 1 ft., against a train resistance of 25 lb. per ton and at a speed of 16 miles per hr.

485. *Solution.* From the rule of Art. 475 the horsepower required to overcome train resistance is 21.3; from the rule of Art. 483, $40{,}000 \times 0.0125 = 500$; $500 \times 23.5 = 11{,}750$; $11{,}750 \div 550 =$ 21.3 horsepower to overcome the grade. 21.3 horsepower + 21.3 hp. = 42.6 hp.

486. Calculation of Grade Rise. The per cent. rise of grade is the distance that a car is raised in traveling 100 ft. on the grade. Thus on a 6 per cent. grade, a car running 100 ft. on the rail would be raised 6 ft. The distance that a car is raised by traveling a given distance on a grade of given per cent. can be gotten as follows:—

487. *Rule.* To get the rise in feet for a given rail distance in feet on a grade of given per cent., Multiply the rail distance in feet by the per cent. of the grade and divide by 100.

488. *Example.* A car runs 344 ft. on a 1.25 per

cent. grade. Through what vertical distance is the car raised by the grade?

489. *Solution.* $344 \times 1.25 = 430$; and $430 \div 100 = 4.3$ ft.

490. Calculation of Per Cent Grade. Knowing the rail length of the grade and the rise from end to end, the per cent. of the grade can be calculated from the following rule:—

491. *Rule.* To get the per cent. of a grade from its rise and length along the rail, Divide $100 \times$ rise (ft.) by rail distance in feet.

492. *Example.* The rail length of a grade being 344 ft. and its rise, 4.3 ft., wanted the per cent. of the grade.

493. *Solution.* $100 \times 4.3 = 430$; and $430 \div 344 = 1.25$ per cent.

494. *Note.* As a rule the grade rise is determined with an engineer's level, but it can be approximated by sighting over the tops of rods of different lengths.

TOTAL HORSEPOWER OF OPERATION

495. The horsepower required to overcome train, grade and acceleration resistances have been considered. The horsepower required to overcome the simultaneous effects of all is here called the *total horsepower of operation;* it can be calculated as follows:—

496. *Rule.* To find the total horsepower required to overcome specified conditions of train resistance, grade, acceleration: calculate the horsepower of train resistance by the rule of Art. 479,

the horsepower of acceleration, by the Rules of Arts. 428 and 436 and the horsepower of the grade by the rule of Art. 483; then add these values to get the total horsepower of operation.

497. *Example.* Wanted, the total horsepower of operation required to accelerate a 20-ton car 1.23 miles per hr. per sec. on a 1.25 per cent. grade, against a train resistance of 25 lb. per ton; the final speed to be 16 miles per hr.

498. *Solution.* From the rule of Art. 479, $16 \times 20 \times 25 = 8{,}000$; and $8{,}000 \div 375 = 21.3$, average horsepower required to overcome the train resistance.

From the rule of Art. 428, $20 \times 1.23 \times 91.2 = 2{,}243.52$ lb., force of acceleration required. From the rule of Art. 436, 2,243.52 lb. $\times 152$ ft. $= 341{,}015$ ft.-lb.; and $550 \times 13 = 7{,}150$; and $341{,}015 \div 7{,}150 = 47.6$ hp. required to overcome the resistance of acceleration.

From the rule of Art. 483, 40,000 lb. $\times 0.0125$ ft. $= 500$ ft.-lb., the total work done per rail-ft. of grade; 500×11.7 ft. per sec. $= 5{,}850$ ft.-lb. of work done per second; $5{,}850 \div 550 = 10.6$ hp. required to overcome the grade.

21.3 hp. + 47.6 hp. + 10.6 hp. = 79.5 hp., total.

499. *Note.* The 152 ft. is gotten by multiplying the 11.7, average speed in ft. per sec., by 13 sec., the time of acceleration.

500. *Note.* The time of acceleration, 13 sec., is gotten by dividing the maximum speed, 16 miles

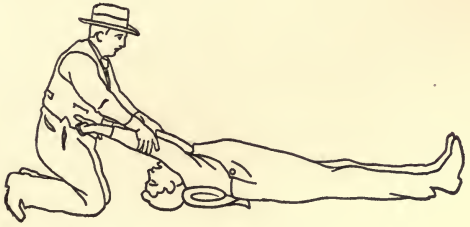
per hr. by the acceleration, 1.23 miles per hr. per sec.

501. *Note.* The rise per foot of a 1.25 per cent. grade is 0.0125 ft.

HELP TO THE INJURED

REVIVING SHOCKED PERSONS

502. The following directions for reviving persons from the effects of electric shock (or apparent drowning) are due in substance to Augustin Goelet, M.D., and are adapted from the *Electrical World and Engineer* of September 6, 1902. In all cases the operations described are to be begun without delay and continued until the arrival of a physician.



72

503. *Directions.* I. Remove the body from the live conductor; if in mid air, poke it loose with a wooden pole and catch it in a blanket held at the four corners, unless there are present facilities and persons qualified safely to use more refined methods. If on the surface, use a dry stick or protect the hands with dry clothing.

II. Turn the body upon the back, loosen the clothing around the neck and chest and waist and place a rolled up coat under the shoulders to throw the head back and mouth open. Kneeling at the victim's head, seize both arms and draw them to full length and almost together over the head, as in Fig. 72, to expand the chest and open the windpipe; hold this position for two or three seconds; next carry the arms down to the sides, Fig. 73 showing the halfway position, and front of the chest, firmly compressing the chest walls, as indicated in Fig. 74,

FIG. 73

to expel the air from the lungs. These successive operations of drawing the arms back over the head almost together and then bending them as in Fig. 73, and finally compressing them on the chest side walls, as in Fig. 74, must be repeated from sixteen to eighteen times per minute and continued ceaselessly for at least an hour or until the breathing is normal. (This method has been known to resuscitate patients who had been under water several hours.)

III. While artificial breathing is being thus conducted, a second person should grasp the patient's tongue with a handkerchief (forcing the teeth apart with a knife or piece of wood, if necessary) and pull the tongue out in step with the stretching of the arms and allowing it to recede into the mouth when the chest is compressed.

FIG. 74

504. *Note.* Dashing cold water in the face, brisk rubbing of the spine with ice or alternate heating and cooling of the region over the heart all tend to produce a gasp and thereby start breathing, which should then be continued artificially, until it becomes natural. It is both useless and unwise to try to revive the patient by pouring stimulants down the throat. In all cases SEND FOR A PHYSICIAN.

RELIEVING BURNS

505. The simplest and most satisfactory relief for an electric burn is to immerse the affected part in a mixture of linseed oil and soda and to keep it

there until all soreness is gone. Where numbers of men are employed, a barrel of this mixture should be kept on hand. In case of severe body burns, the body can be wrapped in bandages to be kept saturated with the oil and soda mixture. In emergencies, the patient can be stood in the barrel.

REHEARSAL QUESTIONS

1. How does height of trolley wire affect trolley pressure?
2. In what locations is the pressure apt to be excessive?
3. In what locations is it likely to be deficient?
4. Why is wheel jumping at steam crossings dangerous?
5. What is the object of the rough pressure test?
6. How is the rough pressure test conducted?
7. Can a spring scale be applied to pressure testing? How?
8. At what angle is the scale preferably applied?
9. What is the advantage of applying the scale vertically?
10. Why does the vertical pull exceed that at right angles?
11. Why should the stretch of test wire be free from sag?
12. What is meant by the pole-roof angle of a trolley pole?
13. Is trolley pressure affected by length of pole? Height of car?
14. Why do the pressures vary on similar cars in like service?
15. What are the effects of excessive trolley pressure?
16. State the effects of deficient trolley pressure.
17. Why does pressure required vary with the car speed?
18. How may the most desirable pressure be determined?
19. Of what does a car house plow pressure test consist?
20. Describe the shop pressure test for electric plows.
21. What would be the effect of excessive plow shoe pressure?
22. What would be the effect of deficient plow shoe pressure?
23. What is the approximate pressure per square inch on plow shoes?
24. What is meant by instantaneous blowing test of a fuse?

25. What is meant by the time element blowing test of a fuse?
26. Where can such a test be used to advantage?
27. What is meant by the operating test of a fuse?
28. State the disadvantage if a fuse is too large. Too small.
29. Should cars of different weights and capacities be fused alike?
30. State a rule for finding the size of a copper fuse.
31. Give several reasons that justify the use of copper fuses?
32. What conditions affect the capacity of a fuse?
33. State the advantages of circuit breaker adjustments?
34. Does breaker adjustment decrease the current demand per car?
35. Does it educate motormen to careful controller handling?
36. Describe the limit circuit breaker test.
37. What is the disadvantage of the ammeter breaker test?
38. Give the dimensions of a useful size of water rheostat.
39. What is the advantage of liberal cross-section of water?
40. How may the resistance of water be decreased? Increased?
41. Why may a barrel not be used indoors as a rheostat?
42. Give one method of attaching test lines to car breakers.
43. Name the requirements of the controller cylinder interlocks.
44. State the danger of reversing a car with the power on.
45. Why are reverse handles made unremovable with power on?
46. Why are main cylinders immovable with the reverse "off"?
47. How can opposite reverses be maliciously turned oppositely?

48. Why should there be but one reverse handle to a car?
49. What is the object of the main cylinder interference?
50. With the interference out of order, what may happen?
51. What is meant by vertical alinement of fingers? Horizontal?
52. How can the alinements be tested? Define notch spacing.
53. To what may incorrect notch spacing be due? State effects.
54. What indications fix notch spacing defects in the cylinder?
55. What is the object of controller open circuit test? How made?
56. What knowledge is required to make such a test?
57. In the absence of such knowledge what aid is necessary?
58. What is meant by a controller complete circuit test?
59. Describe the method of making such a test on the bench.
60. Describe the controller short-circuit test.
61. Is a ground fault a special case of short-circuit?
62. What testing precautions must be taken on metal-lined benches?
63. Are conduit systems generally grounded by faults?
64. Name twenty features of controller inspection.
65. Are controller frames grounded on ground return systems? Why?
66. Are they internally grounded? Externally? How?
67. How are controller frames tested for ground?
68. Is it customary to ground metallic return controllers?
69. Will an open circuit in one controller affect operation in both?
70. An open circuit affects both ends of a car; is it in a controller?
71. Applying power with reverses oppositely set, results how?
72. How can the resistance of a starting coil be measured?

73. What best governs the resistance of a starting coil?
74. A coil starts a car smoothly; how would it start a lighter car? A heavier car? What is the best test for starting coils?
75. If a coil heats too much, what should be done?
76. In changing its current capacity, is resistance considered?
77. Do standard coils minimize controller abuses?
78. Do standard coils affect circuit-breaker adjustments? How?
79. Define starting coil section test. Describe the test.
80. Voltage applied to a series circuit distributes how?
81. In section tests, why must sets of drops be repeated?
82. Give an empirical rule for sectioning starting coils.
83. Is the section test adapted to locating starting coil faults?
84. What is meant by trial notching with a starting coil?
85. How will cars start with resistance too low? Too high?
86. What conditions must be considered in insulating coils?
87. Can a poorly insulated coil or hanger shock a passenger?
88. Describe the voltmeter test for starting coil insulation. For leakage path resistance. For probable voltage of a shock.
89. What are the spark points of a lightning arrester? The air gap?
90. How does a broken trolley or ground wire affect arrester operation?
91. Should the air-gap of an arrester be adjusted? How and to what thickness? State precautions in applying the gage.
92. How can the arrester trolley and ground wires be tested for continuity?
93. Does location of trolley tap affect manner of test?
94. Do all types of arrester employ an air-gap?

95. How will open circuit in the lightning path affect operation?
96. How will open circuit in the blow-out coil path affect operation?
97. What is meant by the operating test on arresters?
98. Why should an air-gap be thinner than insulation on devices?
99. When is it most important that arresters be inspected?
100. How may the effectiveness of the blow-out device be tested?
101. What is the object of the extra resistance in the test?
102. Does trolley current follow a lightning discharge to ground?
103. What is the object of motor rotation test? Give connections?
104. How are motions of car and armature related?
105. What signs have the A's, F's and E's in controllers?
106. Do resistance connections affect direction of car motion?
107. How will changing field jumper to other side of motor result?
108. Why is it desirable to make top field leads positive?
109. Why are armature wires crossed in No. 2 controller?
110. Describe cable tagging, stating precautions to be taken.
111. How does systematic tagging save labor in equipping?
112. Is crossing of armature wires ever left to the wiremen?
113. What is the cable insulation test? How made on piped cars?
114. Is high voltage test necessary on cars that are not piped?
115. Define brush spacing. Radial alinement. Symmetry of set.

116. Why do brushes span fewer bars on an old commutator than on a new one of the same kind?
117. What is the radiality requirement of bevel edge brushes?
118. On a level surface car motor, where is the line of symmetry?
119. Why are hand holes shifted? State the effect on symmetry.
120. Name two types of brush holders. Give characteristic of yoke type.
121. Of what type are most General Electric railway motor brush holders? Westinghouse?
122. Can a properly installed independent holder set brushes off?
123. To what main irregularity is this type liable? The yoke type?
124. How do variable shrinkages affect the set of holders?
125. What precautions must be had in regard to yoke wood? Is it affected by heat? Are factory yokes specially treated?
126. What is meant by wrong brush spacing?
127. What is the symptom of displacement of one holder? Two?
128. Which is preferable, brushes too close or too far apart?
129. State the effect of lack of symmetry. How is armature reaction involved?
130. What is the initial effect of lack of radial alinement?
131. What is its effect as the commutator wears?
132. How is the set affected by a long bracket? A short bracket?
133. How do defects of radial alinement and yoke height differ?
134. Define canted brush. To what may it be due?
135. How can yoke fault be distinguished from holder fault?
136. What may cause canting of an independent holder?

137. How does bearing wear affect brush set? How remedied?
138. Excessive brush pressure results how? How, deficient pressure?
139. What operating conditions govern the pressure required?
140. How is brush pressure expressed? In what units generally?
141. Between what limits do brush pressures vary?
142. How can pressure be measured? What precautions are taken?
143. How are the contact areas of straight and beveled brushes found? The pressure in pounds per square inch is calculated how?
144. Distance from commutator means what? What should it be?
145. State the effect if the distance is too great. Too little.
146. How can the distance be standardized with a gage?
147. What is meant by (a) Counting off brushes? (b) Center to center count? (c) Inside edge count? How is center to center count gotten?
148. How may inside edge count be gotten from center to center count?
149. State the practical advantage of the inside edge count.
150. What is the immediate effect of error in brush setting?
151. To what conditions may resulting sparking lead?
152. How should holders be made standard? Maintained standard?
153. How may armature insulation be tested on the floor?
154. How on a car? Why are the brushes then drawn?
155. Is there a ground test for uninstalled shelless field coils?
156. Describe insulation test for installed fields. For brush holders.

157. Is badly charred condition of a brush yoke always evident?
158. What is the operating symptom of an open circuit field?
159. May such open circuit ever be repaired without opening the motor?
160. Describe the bell circuit test for open circuit field.
161. Can a fault show open circuit and ground too? How can it be proven by test?
162. Will one open circuit in an armature open the motor circuit?
163. What is the operating symptom of an open circuit armature?
164. How can open circuit in an armature be detected (a) By resistance measurement? (b) By voltmeter? (c) By a second open circuit?
165. Describe the drop test for open circuit fields.
166. What is the operating symptom of short-circuited armature?
167. How does it differ in action from a grounded armature?
168. Describe the compass tests for installed and uninstalled field coils. How can the first test be made without current?
169. What is the effect of a reversely-wound field coil?
170. In what other way can the polarity of a coil be reversed?
171. Why is a coil in error worse than a wrongly connected one?
172. What difficulty may be encountered in handling a compass?
173. What is meant by carbonized field coils? Is it very common?
174. How can a well carbonized coil be tested in the motor?
175. Why must the pole-pieces be tight? How is it sometimes done?

176. In bench testing of field coils how is compression secured?
177. Describe the combination test. Where and why is one turn cut?
178. What does a high insulation deflection mean? A low resistance drop?
179. What advantage has the combined test over the resistance test?
180. What does zero insulation deflection mean? Maximum resistance drop?
181. How can the cut field turn be easily repaired?
182. What is meant by testing armature clearance?
183. Describe the test by light. By gage. By schedule.
184. State the disadvantage of a wedge-shaped gage.
185. What is the life of a $\frac{1}{16}$ in. of well lubricated babbitt?
186. What does a hot motor mean and what condition does it indicate?
187. How is armature rubbing apt to affect breakers and fuses?
188. Do armatures ever rub the upper pole-pieces?
189. Do pole-pieces ever go down on the armature?
190. Can rubbing be caused by eccentric bearings? Worn housings?
191. How are air-gap thickness and motor sparking related?
192. What is the object of a motor balance test?
193. How is motor balance affected by (a) Open motor frame? (b) A baked, short-circuited or wrongly connected field coil? (c) Coil wound with wrong size of wire? (d) Dissimilar armatures? (e) Difference in gearing or wheel sizes? (f) Difference in brush set?
194. Assuming balance, state the voltage distribution in series.
195. Assuming balance, state the current division in parallel.

196. Where a balance test shows discrepancy, what must be done?
197. Describe the voltmeter balance test on a two-motor car.
198. Can such a test be made with a single voltmeter? How?
199. What difference in readings is considered safe to pass?
200. Why will the sum of the readings be less than line voltage?
201. Should readings be simultaneous? Approximate their sum.
202. How is the per cent. difference in the readings calculated?
203. Describe the voltmeter balance test on a four-motor car.
204. How and why are two of the motors to be cut out?
205. Are the remaining two motors in series or in parallel?
206. Describe the lamp balance test. State its limitations.
207. On what principles do the lamp indications depend?
208. How can the number of lamps to be used in series be calculated?
209. State the reason for interchanging the test circuits.
210. How and why may some of the lamps be short-circuited?
211. Will the test detect badly roasted or wrongly connected coils?
212. Have 50-volt lamps any advantage in such a balance test?
213. How can the voltage active per motor be calculated?
214. Could the preceding tests be made on motors in parallel?
215. Could the volts per motor differ and the amperes per motor not?
216. Could the motors take the same voltage but different current?

217. With motors in series why cannot ammeters indicate usefully?
218. With motors in parallel why cannot voltmeters indicate usefully?
219. Could ammeters in series indicate differently? Why?
220. Could voltmeters in parallel indicate differently? Why?
221. Why are the ammeters cut in with the motor fields?
222. When must they be cut in with the motor armatures?
223. Describe the ammeter balance test on a four-motor car.
224. Why is it unnecessary to separate the motors?
225. Can balance tests be made with milli-voltmeters?
226. Can low reading voltmeters be used to make such a test?
227. These meters with their shunts constitute what?
228. In what circuit is the meter shunt connected?
229. What equipment part can be used as low reading voltmeter shunt? As milli-voltmeter shunt?
230. Need the motor current corresponding to deflections be known?
231. What is meant by the comparison of deflections?
232. What precaution is to be observed in the test?
233. Describe the milli-voltmeter balance test on a two-motor car.
234. Why is it undesirable that the shunts heat? How avoided?
235. What precaution is taken in connecting the meters?
236. How can the meters be calibrated (a) To read the same? (b) To read direct? (c) One to read in terms of the other?
237. What is meant by (a) Calibrating? (b) Direct reading?
238. Can milli-voltmeters be bought with direct reading shunts?
239. Will the shunt of one meter do for another meter?

240. How can a balance test be run with one millivoltmeter?
241. State the objection to using one meter in a balance test.
242. Of what value are balance tests in looking for carbonization?
243. When is its value a minimum? How can its value be improved?
244. Will it show up baking before it causes operating troubles?
245. What is the first operating symptom of carbonization?
246. How is it apt to affect car fuses and circuit-breakers?
247. What are the objects of factory and shop motor heat tests?
248. How do carbonized fields affect motor lubricant?
249. How are field strength and motor current related on a car?
250. Does this same relation exist on the heating test rack?
251. With same current, will a baked field heat like a good one?
252. How is the motor loaded in a rack heat test?
253. For how long is the test run in each direction?
254. When is a dynamo said to be self-excited? Separately excited?
255. In a self-excited test, why has each machine a reverse switch?
256. May there be difficulty in making the dynamo generate?
257. How may this be overcome? Explain the action of the fuse.
258. How is the load on the motor regulated?
259. How is the dynamo field excited in the separately excited test?
260. Why are there no reverse switches in the dynamo fields?

261. Is this test well adapted to heat measurements? Why not?
262. Describe the self-excited test. Will it show ground faults?
263. State how a circuit is affected by one ground. Two grounds.
264. Briefly describe the running of a shop heat test.
265. Why is speed taken initially and finally? Why does initial speed exceed final? How should current be in speed counts?
266. How is speed at standard voltage gotten from the test speed?
267. What other conditions are watched during the shop test?
268. Briefly describe the temperature test on a car motor.
269. Why must the temperature of the atmosphere be noted?
270. How is the rise in resistance of the winding gotten? How is the temperature rise gotten from the rise in resistance?
271. How is the final resistance of the winding gotten? Why is the calculated temperature greater than thermometer reading?
272. How can fahrenheit degrees be converted into centigrade degrees? How centigrade into fahrenheit?
273. Define efficiency of a machine. Its input. Its output.
274. Can any machine give out all the work put into it?
275. Is this impossibility related in any way to perpetual motion?
276. Define commercial efficiency of a motor. Electrical efficiency of a motor.
277. How are efficiencies generally expressed?
278. How can the decimal efficiency be converted into per cent. efficiency?
279. Must the input and output be expressed in the same units?

280. Which is the greater, the cold or hot efficiency?
281. What is internal resistance? How related to electrical efficiency?
282. Which efficiency interests buyers, hot or cold?
283. Must the motor be heated before an efficiency test? Why?
284. What measurements are made in taking commercial efficiency tests?
285. The electrical measurements are how made? The mechanical?
286. Describe a brake and state the object of the water.
287. Why are the weights guarded? How is the speed measured?
288. How is the brake power expressed in watts? How reduced to horsepower?
289. Why is the constant 1.36 used in the conversion rule?
290. What is the direct object of energy absorption tests?
291. When should heat, light and compressor circuits be cut out?
292. When should test record start and end? How about delays?
293. Describe the watt-hour meter test. Give connections of meter.
294. State the advantage of the watt-hour meter method. Disadvantage.
295. What is meant by the constant of a watt-hour meter?
296. How should the instrument be protected from jolts?
297. Describe the indicating wattmeter test. What does the reading indicate?
298. How are the watt-hours absorption calculated from the readings?
299. How can equi-spaced readings be gotten?
300. How are the meters connected in a voltmeter-ammeter test?
301. What means may be taken to get simultaneous readings?

302. What temptation must a tester overcome? How must the meters be supported? What precaution in regard to capacity?
303. What is the object of the short-circuiting switch? Will the ammeter indicate with it closed? What precaution is necessary?
304. How are the completed readings handled? What do individual products represent? To what readings do they correspond?
305. When and how may car-weight be gotten by two weighings?
306. How may pound weight be converted into ton weight? Ton weight into pound weight?
307. How is total horsepower of equipment gotten? Full load current?
308. In what unit are current values expressed?
309. The actual duration of an absorption test means what?
310. How can duration in minutes be converted into duration in hours?
311. How may distance generally be gotten? How from rail count?
312. How can distance in feet be converted into distance in miles?
313. What is the maximum voltage of the test? The minimum voltage?
314. When may a reading be rejected? How is it then treated?
315. How is the average voltage of the test obtained?
316. What means total ammeter readings? Total current readings?
317. In what subsequent calculations is each used?
318. How are the average current of all and of current readings gotten?
319. Why are the sums of ammeter and current readings the same?

320. What is the maximum current reading of an absorption test?
321. In case of short-circuit what current reading is recorded?
322. In case of an unrecorded maximum reading, what is done?
323. Why are the power and current readings simultaneously zero?
324. What is the maximum power reading of an absorption test?
325. Do maximum power and current readings necessarily coincide?
326. What is meant by total and actual power readings?
327. In what subsequent calculations is each used?
328. What is the average power of all readings and how obtained?
329. How is the average power of current readings calculated?
330. How is average speed gotten? Define total energy absorbed.
331. How is total energy expressed in watt-hours? In kilowatt-hours?
332. How can kilowatt-hours be converted into horsepower-hours?
333. How are the average kilowatts calculated? When used?
334. How are kilowatt-hours per mile calculated? Kilowatt-hours per ton?
335. How are kilowatt-hours per ton per hour calculated? Kilowatt-hours per ton per mile?
336. How can the absorption test be made more instructive?
337. What power information do grade notes afford?
338. State the objection to the voltmeter-ammeter absorption test.
339. State the advantages of the method.

340. Has average volts multiplied by average amperes any certain meaning?
341. What is the objection to using it as the average power of the test?
342. Describe the rail-count, pole-count and minutes per half mile speed tests.
343. Define acceleration. How is the term generally accepted?
344. In what units is acceleration generally expressed?
345. How can miles per hour per second be converted into feet per second per second and vice versa?
346. What is meant by time of acceleration and how obtained?
347. How should correctness of the time be insured?
348. What is meant by distance of acceleration and how obtained?
349. How are maximum and average speeds during acceleration obtained?
350. How can the average speed be gotten from the maximum speed?
351. What is meant by force of acceleration? How calculated?
352. What is meant by horsepower of acceleration? How is it calculated?
353. Are the calculated force and horsepower of acceleration averages?
354. Is the acceleration of an electric car uniform?
355. Define retardation. To what is it generally due?
356. Is the time required to set a brake easily obtained?
357. What advantage has an air-brake in this respect?
358. How is the force of an air-brake applied? A hand-brake?
359. How is accuracy secured in retardation tests?
360. How are retardations in miles per hour per second and feet per second per second obtained?
361. What do distance and average speed of retardation mean and how obtained?

362. What does maximum speed of retardation mean and how gotten from average speed?
363. Does friction oppose acceleration or retardation?
364. Why can a car be retarded from a given speed to rest in less time and distance than it can be accelerated to that speed?
365. How does controller handling affect uniform acceleration?
366. What is usually the object of an acceleration test?
367. How do motormen's efforts at rapid acceleration result?
368. What are the objects of retardation tests?
369. What is meant by train resistance? By coasting?
370. What agencies stop a car coasting on an up grade?
371. Describe a train resistance test on level track.
372. How is total train resistance calculated? Train resistance per ton?
373. What is meant by rise per foot of a grade? How calculated?
374. What is meant by per cent. of grade? How may it be calculated?
375. How can the retarding effect of a grade be calculated?
376. What is meant by the horsepower of traction?
377. How can it be calculated? (Two methods.)
378. How can the horsepower of traction on grades be calculated?
379. What is meant by the total horsepower of operation?
380. How can a body be removed from a live conductor in mid-air?
381. What precaution must be taken if the body is on the surface?
382. In artificial respiration, why are the shoulders raised?
383. What motions are used to expand the victim's chest?
384. The position for chest expansion is held how long?

385. How many times per minute should the complete cycle of operations be repeated and for how long should they be continued?
386. What tongue movements should accompany artificial respiration?
387. If the teeth are clenched, how may they be parted?
388. Does cold water dashed in the face induce respiration?
389. Does brisk rubbing of the spine induce a gasp?
390. What effect has alternate warming and cooling of the region over the heart?
391. Should stimulants be poured down the patient's throat?
392. Give a good application for electric burns.
393. In emergency cases how may the mixture be applied to body burns?

INDEX

Armature,
clearance of, 66–69
ground in, 60
insulation of, 55
open circuit, 57–59
short circuit, 60
wear of, 47

Brush holders,
alinement of, 42–45
wear of armature, 47
Brush maintenance, 54
miscellany, 51–56
pressure, 48–50
spacing, 45
Burns, 133

Canted brushes
commutator "counting off," 47
height of, bracket, 46
symmetry of, 43
types of, 44
Car-wiring cables, 39–40
Circuit breakers,
adjustment of, ammeter method, 11
adjustment of, limit breaker method, 12
periodic tests of, 10
Copper wire used as fuse, 8

Dynamos,
self excited, 84
separately excited, 85
efficiency of, commercial, 90
efficiency of, electrical, 90

Energy, absorption of, see tests

Field coils, see tests
Fuses, see tests

Help to injured, 131

Insulation,
of armature, 55
of brush holder, 56
of car cable, 40
of conduit, 5
of field coil, 55
of starting coil, 29

Lightning arresters,
air gap adjustment, 35
connections of, 33–34
operating, 35

Millivoltmeter to Calibrate. 80–81
Motor—see tests

Pressure—see tests
trolley—see tests, 1

Shock, aid in case of, 131
Starting coil,
resistance of—see tests, 25

Temperature, rise, calculated from the increase in resistance, 88
Test lines, method of attaching, 13–14

TESTS
Acceleration tests, 114
Armature test for ground in, 60
for insulation, 55
for open circuit, 57–59
for short circuit, 60

Balance test, 71–78
Brush holder, insulation test, 56
pressure test, 49

Car-wiring cable insulation test, 40
Controllers,
Electrical tests,
for ground in, 21
for open circuit in, 18
for short circuit in, 20
inspection of, 22
Mechanical tests,
for alinement, 16–17
for interference, 15
for interlocks, 15
Controllers—*Continued*
for notch spacing, 17
precautions, 23

Efficiency test,
for commercial efficiency, 92
for electrical efficiency, 91
Energy absorption tests,
by integrating wattmeter method, 96
by volt-ammeter method, 97
by watt hour meter method, 95

Field coils tests.
for carbonization, 63–66-82
for insulation, 55
for open circuit, 56
for polarity, 61–62
for short circuit, 59
Fuses, tests for,
blowing test, 7
calculating capacity of copper wire, 8
instantaneous test, 7
operating test, 8
requirements for test, 9
time element, 7

Heat test, 83
Horsepower of traction tests, 125
total tests, 128

Lightning arresters, tests, 35

Motor balance test,
on two-motor car, 71, 74, 76, 78
on four-motor car, 73–78
heat test, 83

Pressure tests,
conduit, 4
third rail, 6
trolley, 1–3

Retardation test, 119

Speed test, 112
Starting coils,
insulation test, 29
section test, 25
shock test, 30

Temperature test, 88
Train resistance test, 122
Time element of fuse, 7
Trolley—see tests

Water rheostat, 13

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